ILLINOIS STATE WATER SURVEY DIV.

ACTIVATED SLUDGE STUDIES

STATE OF ILLINOIS

DEPARTMENT OF REGISTRATION AND EDUCATION.

DIVISION OF THE

STATE WATER SURVEY

A. M. BUSWELL, Chief.

BULLETIN NO. 18

Activated Sludge Studies

1920—1922

(Printed by authority of the State of Illinois

URBANA, ILLINOIS

PUBLICATIONS OF THE STATE WATER SURVEY.

No. 1. Chemical survey of the waters of Illinois. Preliminary Report. 98 pp., 3 pl., 1 map. 1897. (Out of print.)

No. 2. Chemical survey of the waters of Illinois. Report for the years 1897-1903. XVI+254 pp., 55 pl. 1905. (Out of print.)

No. 3. Chemical and biological survey of the waters of Illinois. Report for year ending August 31, 1906. 30 pp., 5 cuts. 1906.

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STATE OF ILLINOIS.

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LETTER OF TRANSMITTAL.

State of Illinois,
Department of Registration and Education,
State Water Survey Division.

Urbana, Illinois, May 1, 1920.

A. M. Shelton, Chairman, and Members of the Board of Natural Resources and Conservation Advisors:

Gentlemen—Herewith I submit report of the investigations of the activated sludge process of sewage disposal carried on by this Division during 1920-21 and 22 and request that it be printed as Bulletin No. 18.

Since the Directors' report includes a statement of the general activities of all Divisions, it has seemed advisable to discontinue the publication of an annual report of this Division and to prepare instead summaries of our various investigations as they are completed.

Acknowledgment should be made to Professor Edward Bartow, Chief of the State Water Survey to September 1, 1920, who was retained as consultant until February, 1921; to Mr. C. Lee Peck, who supervised the final stages of installation and early operation of the Dorr-Peck tanks; and to Mr. G. C. Habermeyer, engineer, and Dr. R. E. Greenfield, chemist of the staff of this Division, who took active part in the conferences on the more important problems encountered.

We are indebted to the Dorr Company for the loan of the Dorr thickener mechanisms used in these experiments, and for the license to build tanks after the Dorr-Peck design. The blower was loaned by the Nash Engineering Company, and the air meter by the Rotary Meter Company. The Staley Manufacturing Company of Decatur furnished the two large cypress tanks in which the Dorr-Peck apparatus was installed. The many courtesies extended to the State Water Survey by the cities of Champaign and Urbana greatly assisted the prosecution of the work.

Extensive use has been made of the Bibliography of Activated Sludge, prepared by J. Edward Porter of the General Filtration Company, Rochester, New York.

Respectfully submitted,

A. M. Buswell, *Chief.*

INTRODUCTION.

It is our purpose in the present bulletin to offer first a brief historical survey of progress in the development of the activated sludge process of sewage disposal, and second, with this historical view as a background, to present the chemical and biological data which have been collected during the past year's experimentation with low air operation of an activated sludge plant treating 75,000 gallons per day. For the sake of completeness a historical sketch printed in a previous bulletin will be quoted here:[1]

"The earliest attempts to oxidize sewage by aeration were made by Dupre and Dibdin[2] on the sewage of London, and by Dr. Drown[3] on the sewage of Lawrence, Massachusetts. They found that oxidation accomplished in this way was a very slow process, and accordingly not at all practicable.

In 1892 Mason[4] and Hine conducted experiments on the oxidation of sewage by means of aeration. They concluded that air had but little oxidizing effect on sewage.

In 1894 Waring[5] attempted to apply air on a working scale at New Port, R. I., but his project was unsuccessful.

In 1897 Fowler[6] aerated the effluent from the chemical precipitation tanks at Manchester, England, but without accomplishing any considerable degree of purification. In 1911 aeration was again attempted. Black[7] and Phelps studied the possibility of aerating the sewage of New York City. They used tanks filled with inclined wooden gratings for varying periods up to twenty-four hours. The oxidation was so slight that determinations of nitrogen showed practically no purification, although some measure of improvement was indicated by the incubation tests. Black and Phelps recommended the process for a large-scale installation but it was not adopted.

Clark, Gage and Adams[8] had tried aeration of sewage at the Lawrence Experimental Station, but had been unable to obtain satisfactory results until 1912. In that year, however, they were able to nitrify sewage successfully by aeration for twenty-four hours in a tank containing vertical slabs of slate placed about one inch apart, and covered with a zoogleal mass of colloidal matter deposited from the sewage. They submitted the effluent to further treatment for they did not claim that the aeration would entirely obviate filtration.

Gilbert J. Fowler,[9] of Manchester, England, had tried aeration with some modification on English sewages, but had obtained only indifferent results. Upon his return to England after a visit to Lawrence in 1912, he suggested work on aeration to Edward Ardern and W. T. Lockett,[10] resident chemist and assistant chemist, respectively, at the Davyhulme Sewage Works of Manchester. On April 3, 1914, they reported the remarkable results which they had obtained in their preliminary investigations.

In their first experiment, Ardern and Lockett aerated samples of Manchester sewage in gallon bottles, until complete nitrification was accomplished the aeration was affected by drawing air through the sewage with an ordinary filter pump.

Aeration for about five weeks was required to obtain complete nitrification. The clear oxidized liquid was then removed by decantation, raw sewage added to the deposited sludge, and aeration continued until the sewage was again completely nitrified in six to nine hours.

The sludge which induced such active nitrification was called "activated sludge" by Ardern and Lockett.

In August, 1914, Edward Bartow[11] saw the work in progress at Manchester, and upon his return to this country, suggested that experiments with activated sludge be started at the University of Illinois."

Experiments on the purification of sewage by aeration in the presence of activated sludge were begun at the laboratories of the Illinois State Water Survey in November, 1914, and have been continued to the present date.

The first series carried out by Bartow and Mohlman included experiments in three gallon bottles, a small tank with glass sides five feet deep, and later concrete tanks of ten square feet area, and eight feet five inches deep. This series demonstrated the effect of activated sludge on the rate of nitrification, the superiority of filtros plates as air diffusers over wood diffusers, and furnished data on the ratio of diffuser area to tank area. These experiments are completely reported in Bulletin 13.

During this series of experiments such problems arose as the required area for air diffusion, the nitrogen cycle, the time of aeration, the fertilizing value of the sludge, the required sludge for purification. The fill and draw method proved inadequate and attention was given to the construction of a new plant.

In the summer and fall of 1916, the septic tank designed by Professor A. N. Talbot in 1897 for the city of Champaign was re-

constructed into a continuous-flow plant where the second series of experiments on the activated sludge process was conducted.

The reconstructed plant was designed to treat 200,000 gallons of domestic sewage daily, and consisted of a combined screen chamber and pump, a two-compartment grit chamber, separate aeration and settling tanks, the necessary machinery and accessories for furnishing and measuring the air and sewage. Other parts of the plant consisted of sludge drying beds and a pond, into which the effluent was discharged. A full description of the plant, results and conclusions are given in an article by Professor Edward Bartow.[12]

Recent Progress. In the meantime a relatively enormous amount of experimental work has been in progress throughout the world. Porter's bibliography lists over eighty experimental plants and seventeen municipal activated sludge plants completed or in process of construction at the present date.

In this country a most extensive series of experiments has been carried on at Milwaukee, Wisconsin,[13] leading to the design and construction of an activated sludge disposal plant for the entire city of Milwaukee. A plant has been in operation in Houston, Texas, since 1917. The most recent report on operating results will be found in *Eng. News Record,* **85**, 1128. San Marcos, Texas, with a sewage flow of 150,000 gallons per day, is believed to be the first town in the United States to use activated sludge treatment for its entire sewage.

Considerable progress in the treatment of trade wastes by the activated sludge process has been made by the Sanitary District of Chicago. The British experiments have been along somewhat different lines from the American, and will be described under special headings.

Review of Experiments with Aerators and Automatic Sludge Return. One of the most extensively investigated problems is that of reducing the amount of air necessary for maintenance of the proper operation of the activated sludge process. Unless the cost of operation can be very materially reduced or considerable return realized on the sludge the process will be of very limited application.

We have found in going through the technical and patent literature some thirty articles or patents describing either methods of introducing air into sewage other than by blowing through porous tile, or methods for increasing the period of contact and efficiency of air when once blown into the sewage.

A few of the methods which have been employed with more or less success for the introduction of air into sewage other than by blowing through porous plates will be discussed. Fig. 1 shows illustrations of nine such methods.

Fig. 1a

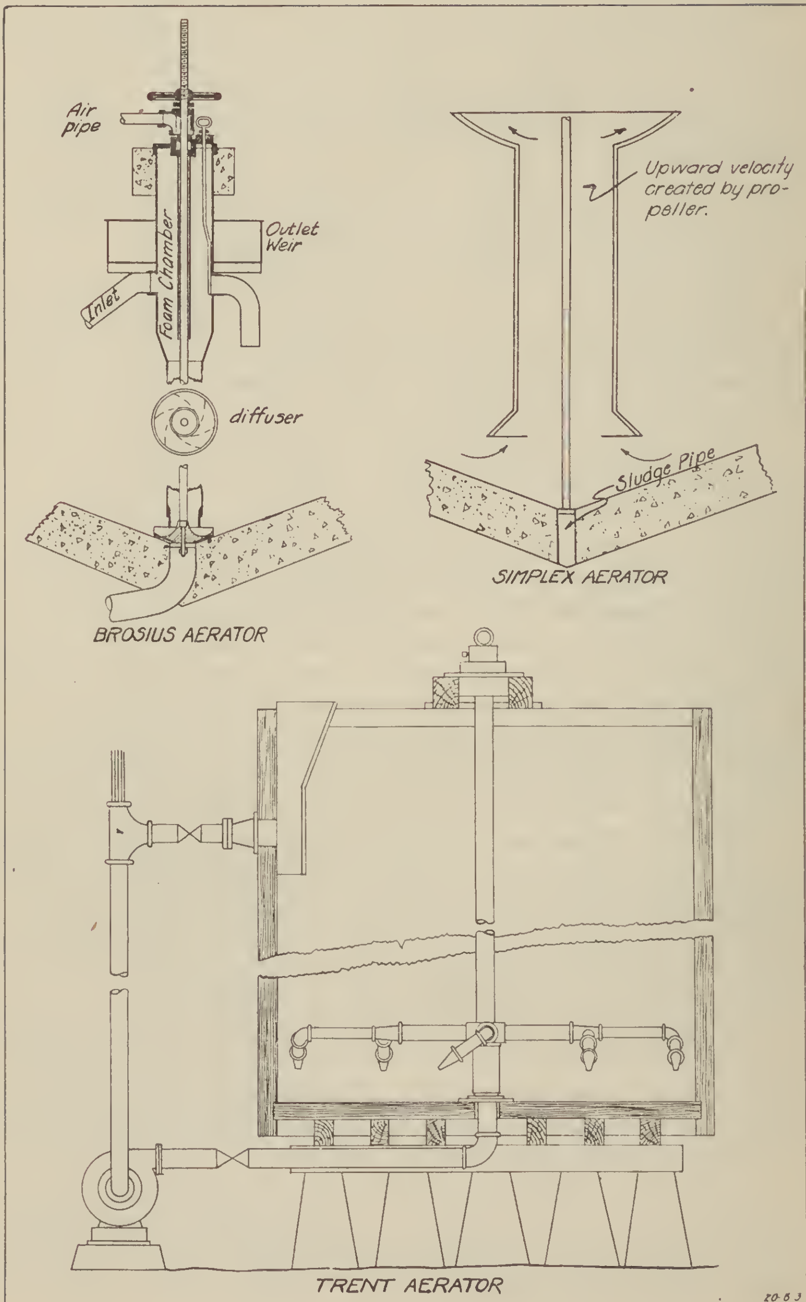
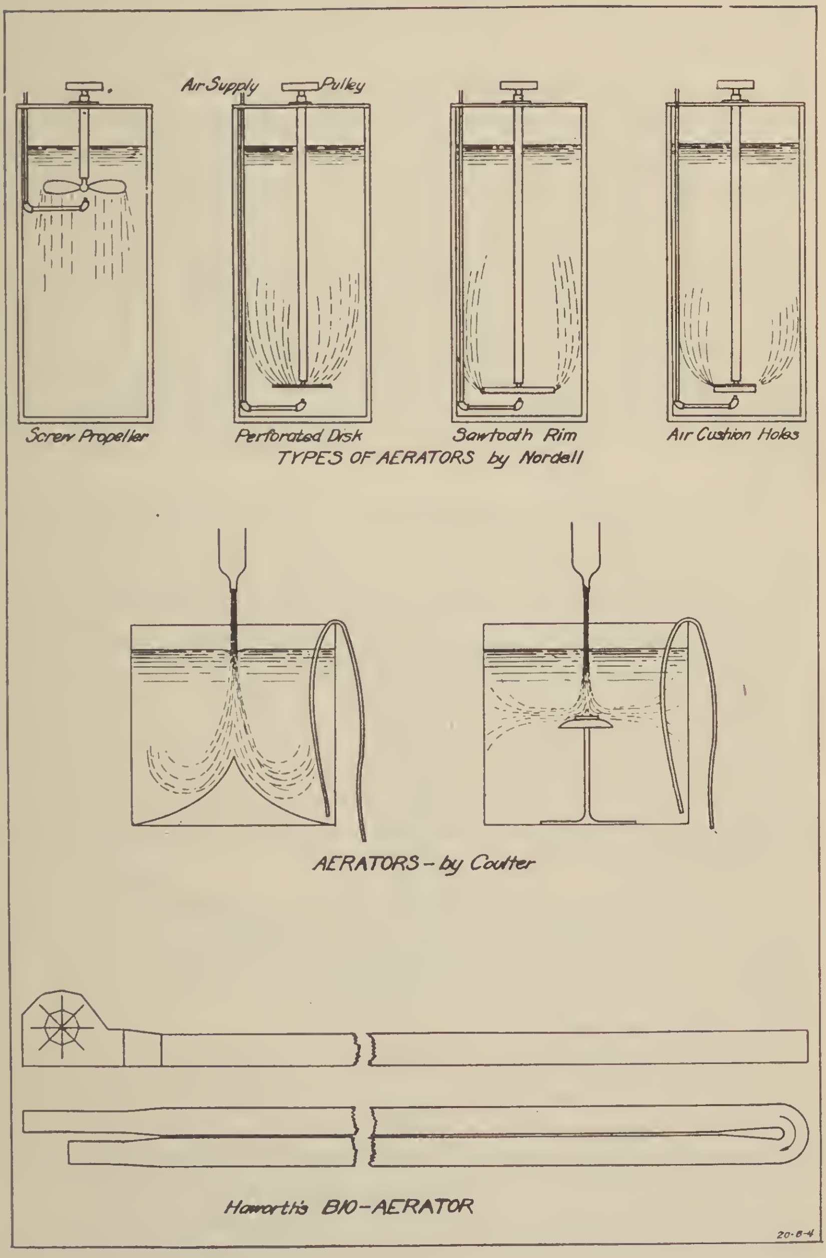

Air pipe
Outlet Weir
Foam Chamber
Inlet
diffuser
BROSIUS AERATOR
Upward velocity created by propeller.
Sludge Pipe
SIMPLEX AERATOR
TRENT AERATOR
20-B 3

Fig. 1b


Air Supply
Pulley
Screw Propeller
Perforated Disk
Sawtooth Rim
Air Cushion Holes
TYPES OF AERATORS by Nordell
AERATORS - by Coulter
Haworth's BIO-AERATOR
20-8-4

Coulter[14] describes experiments in which he forced water under considerable pressure through a nozzle, allowing it to strike upon the surface of the liquid in the tank. The force of the stream carried a considerable amount of air down into the liquid. In fact, by using a large diameter pipe directly beneath the point where the stream struck the liquid in the tank, thereby producing a sort of suction pump, it was found possible to carry air bubbles several feet beneath the surface of the liquid. This method has not to our knowledge been employed on a large scale in purifying sewage.

A second method which was employed by Brosius[15] and Trent[16] independently, produces a mixture of air and liquid by drawing or forcing the liquid rapidly down a vertical pipe at such a rate that air is mechanically carried down with the water. In the Trent apparatus a series of small pipes inside the large vertical downtake pipe facilitated the introduction of air. In neither of these machines were the conditions produced satisfactory for the maintenance of activated sludge.

A third method for introducing air, and one which has been frequently attempted, is that of surface aeration. Haworth[17] appears to have successfully operated an activated sludge plant by surface aeration at Sheffield, England. He causes the sewage and activated sludge to circulate through long channels. These channels are approximately four feet wide and four feet deep. The rate of flow is just sufficient to maintain the sludge in suspension and amounts to one and a half feet per second. Housings cover paddle wheels which force the liquid along the channels. This plant has a capacity of 500,000 gallons of sewage per day and has been in successful operation for over a year. The capacity is equivalent to 1.3 million gallons per acre per day and the power equals 50 h.p. per million gallons.

One point which should be mentioned in connection with the success of this particular experiment is that there is a considerable amount of iron or pickle liquor waste in the raw sewage. It will be remembered that Mumford in describing her M7 called attention to the importance of iron.

Another mechanical process which seems to have found practical application is the "Simplex"[18] installed by the Ames Crosta Sanitary Engineering Company, Ltd., at Bury, England, and elsewhere. "The tank is arranged with a conical bottom, and a central tube coned at the lower end is fixed a few inches from the bottom of the tank, the top portion terminating in a dish, the outer edge of which is raised about half an inch above the top water level. Inside the dish a revolving cone with suitably formed vanes is suspended by means of a vertical

shaft running on ball bearings rotated by shafting and bevel wheels. When the cone is in motion the liquid is thrown out in the form of a film wave, and the liquid and sludge then rise in the central tube to replace the liquid thrown out by the revolving cone. The vanes of the cone are arranged to throw the liquid off so as to strike the surface of the main volume of liquid in the tank in such a manner as to induce a circular motion which causes the liquid to sink in the form of a spiral to the bottom of the tank to be re-circulated. To obtain the necessary amount of agitation and aeration the contents of the tank are circulated once in twenty minutes or three times an hour, the horsepower absorbed being about 12 h.p. per twenty-four hours, run per million gallons. The aeration period ranges from eight to sixteen hours, depending upon the strength of the sewage."

The circulating tank like that described by Hurd[19] has given very good results with about one-half the air required by ordinary aeration tanks. These tanks are built with the diffusers along one side

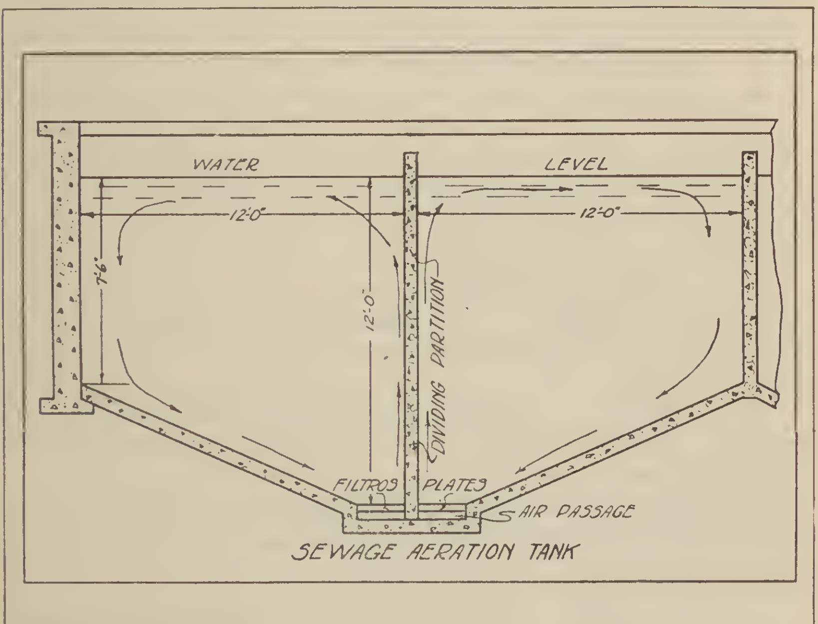


Fig. 2

and a single baffle through the center. The air life effect pumps the liquor over this baffle and returns it underneath. In this way a vigorous circulation is set up. The ratio of diffuser to floor area is from 1:10 to 1:16. Ure[20] has described a similar aerating chamber at Woodstock, Ont. (Fig. 2).

Of the various methods of economizing on air we should like to call attention to the intermittent aeration proposed by G. A. H. Burn.[21] This author suggests cutting off the air during the peak of the power load. If the peak does not last more than three or four hours, satisfactory results might be obtained.

A number of attempts have been made to build activated sludge tanks so that settled sludge could be returned automatically or without pumping to the aeration chamber. Among the previous investigators who have designed such apparatus might be mentioned the following:

Frank[22] describes a tank with a central aerating chamber, and two elevated side chambers with a V cross section, the aeration taking place in the central chamber from which the aerated sewage overflows into the side chambers where sedimentation takes place. The bottoms of these chambers are open so that the settled sludge drops back into the aerating chamber.

Martin[23] describes a cylindrical tank divided into segments. A radial trough is provided for sedimentation, from the bottom of which the settled sludge may be returned to the aerating segment.

G. T. Hammond's[24] tank had an upper and lower chamber, the lower chamber being used for aeration and the upper chamber for sedimentation. The settled sludge could be returned by gravity.

George Moore[25] describes a two-chamber tank with means for discharging the thickened sludge from the lower portion of the second tank directly back to the first.

S. H. Adam's[26] sedimentation tank had an apron roof in which sedimentation took place in the upper portion of the tank on the apron, the settled sludge slipping through a slot into the lower portion of the chamber.

Other means for accomplishing these results have no doubt been employed. The above are mentioned simply as examples of progress in this direction.

The Dorr-Peck tank used in our experiments combined the circulating features of Hurd's tanks with automatic sludge return similar to Frank's system.

CHAPTER I.

Summary.

By A. M. Buswell.

State Water Survey's Third Series of Experiments. Since the present series of experiments involved the use of a novel apparatus previously constructed by a private concern; since, furthermore, a change occurred in the administration of the State Water Survey after the equipment had been ordered and construction of the experimental plant was well under way—but before operation was started—it seems best to insert at this point a brief statement of events preliminary to the third series of investigations.

On his return from the war in July, 1919, Col. Bartow, then Chief of the Water Survey, began plans for an extension of the sewage experiment station with the purpose of continuing investigations into methods of sewage purification. Construction of the experimental plant was commenced in April, 1920. In a previous paper Col. Bartow described the plant as follows:

"A small appropriation had been made for the biennium 1917-19, which was not used and had been reappropriated for the biennium 1919-21. With this as a nucleus the testing station is being revived. The Division funds have been supplemented by contributions of loans of instruments, apparatus, and machinery. The several sanitary districts in the State have promised their cooperation and support. Several manufacturing concerns have loaned apparatus for the work. Tanks, machinery, a blower, a filter press, a continuous filter, and a drier have been obtained in this way.

"It is not proposed to confine the experimental work to the activated sludge process, but to try other methods of sewage treatment as time and funds permit. Many cities in Illinois are located on large streams into which a partly purified sewage can be emptied.

"Owing to the limited amount of funds, all of the schemes cannot be tried at once, and it has been decided to make a study first of the Dorr-Peck modification of the activated sludge process, with additions so that the process will be complete from the raw sewage to the clarified and purified effluent, and the dried sludge ready to be used as a fertilizer."

The following extract from a statement by the Dorr Company published in the *Journal of the Boston Society of Engineers*, v. 7,

p. 255, gives briefly the history of the Dorr-Peck process referred to above.

"The experimental work which led to the development of this process was undertaken with the idea of evolving an apparatus which would secure high efficiency from the air, in order to reduce the operating costs of this desirable system to a figure comparable to that of other systems in general use.

"The idea was conceived that an aeration unit could be designed to effect self-contained sludge circulation and prolonged contact by utilizing the full mechanical efficiency of the escaping air bubbles in the form of an air lift.

"An experimental station was established at Mount Vernon, N. Y., early in 1919, by courtesy of the city authorities, and duplicate aeration units were installed to treat a flow of 45,000 gallons per day of fresh sewage drawn from the lower side of the city bar-screen chamber, containing ¾ inch racks.

"The work was directed by Mr. C. Lee Peck, director of research and development of our Sanitary Engineering Department. Mr. Peck was responsible for the inception and successful development of the experimental work.

"Other vital features affecting the successful aerobic treatment of sewage were developed, which have warranted the adoption of a distinct name for the modification, which has been designated the "Dorr-Peck Process."

"A close study of the biologic control and stimulation has indicated the probability of high nitrogen values being recovered in the sludge, by the use of this system. It is our hope that the time is not far distant when municipal sewage may be treated at a profit. These experiments extended over a period of six months."

After visiting the Mt. Vernon plant Col. Bartow suggested to the Dorr Company that it furnish an apparatus for experimental purposes at Champaign. The Dorr Company, appreciating the advantage of having the apparatus tried out at the State Water Survey, agreed to design the tanks and furnish a considerable amount of equipment for the experiment. The purpose of the experiment was two-fold. First, to investigate further the performance of the Dorr-Peck tank, and second, to determine the effect of various methods of dehydrating and drying upon the sludge produced.

Description of Testing Station. The plant at which the experiments described in this paper were carried out is shown in

Fig. 3. At the left in the foreground is a steam boiler; further back

Fig. 3

and a little to the right, is a Bayley drier, while at the extreme right of the picture are seen the two Dorr-Peck tanks which were operated in series. The small tank was used for drawing and concentrating sludge. In the background is seen the housing over the old Talbot septic tank of historic interest. This tank is also known as the original Champaign septic tank. At the left of and a little behind the drier can be seen the Patterson filter press. A Foxboro gauge makes a continuous permanent record of the amount of the effluent. At the left of the tanks may be seen a portion of the housing covering the motors, pumps and blower. The white collars about the upper portion of the tank are canvas wind breaks provided to prevent disturbance of the sedimentation chamber.

General Character of Sewage. Analyses of the sewage were made on samples of the screened sewage collected hourly and composited into three shift samples for each day. The manner of collection and compositing of samples and the analytical procedure is given on page 116. The determinations were made in accordance with the standard methods of A. P. H. A.

Table III in the appendix gives the analyses and flow of the raw sewage for the entire City of Champaign, as well as for the influent and effluent of the treatment plant. The mean flow was 1.24 million gallons per day.

During the period of high flow, i. e., from 132 to 171 per cent

of the mean flow, large amounts of nitrate, from 2.9 to 6.4 p.p.m. were present. The chlorides and alkalinity were lower than the average in such periods. The largest amount of organic nitrogen, 21.6 p.p.m. was present in the period of minimum flow from August 16-21, 1921.

The turbidity of the raw sewage during the three shift periods of each day was determined separately. Weekly averages from February 22 to September 17, 1921, are tabulated in Table I. Excepting

TABLE I.

RAW SEWAGE: TURBIDITY OF SHIFT SAMPLES.

TIME OF DAY.

For Week of—	8:30 A.M.-4:30 P.M.	4:30 P.M.-12:30 A.M.	12:30 A.M.-8:30 A.M.
Feb. 22-28, 1921	290	220	85
March 1-7, 1921	350	320	90
" 8-14, 1921	260	220	100
" 15-21	175	140	70
" 22-28	160	120	70
March 29-Apr. 4	130	110	55
May 6-13	220	180	85
" 14-21	200	150	60
" 22-28	170	150	60
May 29-June 4	165	140	55
June 5-11	180	170	50
" 12-18	200	170	65
" 19-25	220	180	65
" 26-July 2	250	165	55
July 3-9	240	130	45
" 10-16	240	140	50
" 17-23	230	170	75
" 24-30	240	170	75
Aug. 1-6	240	175	50
" 7-13	250	200	50
" 14-20	250	150	45
" 21-27	250	180	55
Aug. 28-Sept. 3	260	265	50
" 4-10	220	110	35
" 11-17	260	170	50

for the periods of high rain-falls, the turbidity roughly indicates the difference in the strength of the sewage during each day. The turbidity of the night flow was fairly constant while turbidity of the day samples increased from May to September. Table II gives the weekly averages of the screened sewage analyses for the day and night flow. The periods extend from February 22 to September 17, 1921.

Nitrogen Balance. Previous experiments carried on by the Dorr Company with the cooperation of Professor D. D. Jackson of Columbia University, had indicated that the activated sludge process as carried out in this apparatus did not result in the loss of nitrogen. Accordingly, one of our first experiments was to determine whether or not nitrogen was lost in this process.

TABLE II.

Date From—To	Day 8:30 A.M.—12:30 A.M. Turbidity p.p.m.	Oxygen Consumed	NH_3	Alb.	NO_3	NO_2	Alk.	Cl.	Night 12:30 A.M.—8:30 A.M. Turpidity p.p.m.	Oxygen Consumed	NH_3	Alb.	NO_3	NO_2	Alk.	Cl.
Feb. 22-28	290	101	24.0	7.8	.60	.26	445	91	115	41.00	15.	1.77	2.44	.28	376	59
Mar. 1-7	331	91	24.0	5.2	.89	.19	456	106	105	44.80	13.6	1.54	2.05	.28	369	62
" 8-14	280	65	16.0	2.86	2.46	.25	363	97	125	35.00	8.6	1.11	4.22	.21	308	54
" 15-21	230	53	14.5	2.85	2.05	.52	370	97	85	26.0	5.4	1.31	4.34	.38	303	58
" 22-28	230	52	10.5	2.86	4.68	.60	319	85	110	25.0	4.9	1.15	6.63	.33	224	51
Mar. 29-Apr. 4	190	47	10.9	2.40	6.71	.94	328	74	75	28.0	4.9	1.14	10.0	.56	266	53
May 7-13	280	60	16.2	4.11	1.30	.43	410	81	130	28.7	12.0	2.20	5.3	.43	326	61
" 14-20	290	69	18.3	5.82	1.02	.28	447	103	90	30.6	9.8	1.65	4.42	.45	365	70
" 21-27	280	38	14.6	3.36	5.52	.39	364	113	70	28.6	12.6	1.12	8.50	.50	284	72
May 28-Jun. 3	230	49	9.0	2.40	2.97	.96	384	95	90	31.6	4.4	.80	8.57	.68	304	70
Jun. 4-10	241	63	14.2	5.10	1.0	.02	423	126	60	32.1	6.2	1.28	4.78	.34	323	64
" 11-17	330	73	18.2	6.51	.64	.04	448	133	80	32.6	8.4	1.40	2.75	.25	384	86
" 18-24	345	76	19.4	6.00	.60	.01	471	127	110	37.4	9.6	1.54	1.97	.18	402	105
Jun. 25-July 1	300	80	16.6	4.85	.07	.01	474	128	75	40.4	11.2	2.08	.92	.18	402	102
July 2-8	340	68	....	5.50	.29	.01	465	148	80	39.0	10.9	1.66	1.30	.18	370	110
" 9-15	265	71	16.1	4.68	.30	.00	467	143	70	42.6	13.5	1.93	.40	.06	425	106
" 16-22	310	65	23.7	4.57	.04	.00	470	128	95	35.5	12.3	1.71	.85	.24	400	88
" 23-29	300	64	23.4	4.17	.44	.03	467	130	95	39.0	14.0	2.22	.74	.20	346	92
July 29-Aug. 5	320	76	22.0	6.40	.30	.01	454	123	70	39.0	12.6	1.82	.91	.15	355	87
Aug. 6-12	330	83	23.4	6.85	.53	.08	454	130	70	37.8	13.0	1.71	1.22	.16	352	88
" 12-19	370	98	29.1	7.88	.91	.00	476	143	80	49.8	14.6	1.60	1.18	.11	420	103
" 20-26	370	70	20.4	7.97	1.07	.00	466	153	105	36.7	10.9	1.82	.72	.07	337	96
Aug. 27-Sept. 2	370	61	19.5	4.11	.55	.00	464	161	90	36.1	11.7	1.10	.40	.10	392	90
Sept. 3-9	290	59	17.8	3.71	1.11	.25	421	115	90	33.0	8.7	1.65	3.0	.29	353	77
" 10-16	340	68	26.0	4.80	.69	.10	476	118	85	44.0	16.3	2.62	1.1	.09	427	93

For this purpose, hourly samples of the effluent and influent were taken and composited for analysis. The sludge drawn from the apparatus was carefully measured and samples taken. The analyses included determination of free and albuminoid ammonia, nitrates, nitrites, and total organic nitrogen by the Kjeldahl method. The ammonia, nitrate and nitrite, and organic nitrogen all expressed as nitrogen, were added together, converted into pounds per 1,000 gallons and multiplied by the flow for each day. These sums were tabulated for the entire period from December 14, 1920, to February 18, 1921, and are presented in Table III.

TABLE III.

Nitrogen Balance Dec. 14, 1920—Feb. 18, 1921.

Total gallon influent	5,556,310.00
Total gallon effluent	5,468,810.00
Total gallon sludge	87,500.00
Total nitrogen influent, lbs.	1,423.83
Total nitrogen effluent, lbs.	1,332.15
Total nitrogen sludge, lbs.	85.66
Net loss nitrogen, lbs.	6.02
Net loss	.43%

From this table it will be observed that during a run extending over sixty-three days there was a net loss of .43 per cent of nitrogen. Since this amount is within the limits of experimental error, we would conclude that our methods of sampling and analyzing have been sufficiently accurate to keep track of all of the nitrogen, and that in this process there is no volatilization of free ammonia and no reaction taking place whereby gaseous nitrogen is formed. Nor is there any fixation of atmospheric nitrogen. At least if these two reactions occur they neutralize each other in net effect.

Data on the nitrogen balance were collected throughout the experiment and will be found in the body of the report. These results are interesting when compared with results of nitrogen recovery experiments on activated sludge made by other workers with different types of activated sludge tanks, and using much larger quantities of air. For instance, Pearce and Mohlman[27] state that in the summer there is a 41 per cent loss of nitrogen and in the winter a 23 per cent loss of nitrogen. In the Packingtown experiments of these authors it might be noted that 3½ to 4 cubic feet per gallon of air was used. There is, of course, danger of being misled when comparing results obtained on different sewage.

Reversal of Nitrogen Cycle and "Fixation" of Nitrates and Ammonia. In the earlier experiments of the activated sludge process considerable attention was paid to the amount of nitrification, that is, of oxidation of organic nitrogen and ammonia to nitrates.

Metcalf and Eddy,[28] quoting Hatton and Copeland's[29] work, report that in experiments at Milwaukee using as little as .67 cubic feet of air per gallon, clarification was obtained but no marked stabilization of the sewage. Reference to the table of data in the article cited above shows that using that amount of air, there was a complete reduction of nitrites and a 50 per cent reduction of nitrates. By using enough air so that decided nitrate formation was produced, these workers obtained a clear and stable effluent.

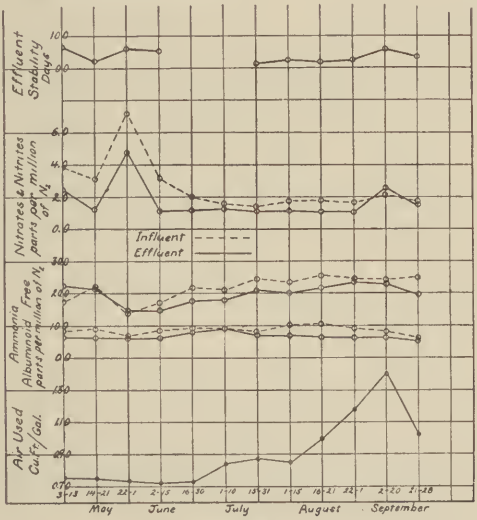


Fig. 4

In Fig. 4 we have plotted the amount of air used in our experiments, the amounts of free and albuminoid ammonia in the effluent and influent, and the amounts of nitrates plus the nitrites in the effluent over the period from May 13 to September 28. From this diagram it is seen that there is an appreciable decrease in both free and albuminoid ammonia as well as in the nitrates in the effluent. It is interesting to note, however, that when the air amounts to 1½ cubic feet per gallon, the effluent and influent curves for nitrates cross. In other words, at this point nitrification takes place. Again, on reducing the air to one cubic foot per gallon there is a reduction of nitrates. This data leads to the conclusion that in the experiments reported in this paper, the nitrification phase of the activated sludge process is entirely absent, and that nitrification is not essential to the success of the process. It is apparently possible under some conditions to produce a clarification and reasonable stabilization of sewage operating with so little air that nitrate oxygen in the raw sewage is actually

consumed by the micro-organisms of the sludge. Attention should be called, however, to the fact that one maximum in the stability curve occurs simultaneously with the maximum influent nitrate and the other with the maximum air. If it is assumed that the free ammonia and nitrates and nitrites are essential as food for the micro-organisms composing the sludge, this may explain why there is no very apparent loss of nitrogen. These compounds are undoubtedly synthesized into microbial protein instead of being reduced to gaseous nitrogen.

Wet Burning of Solids. At the suggestion of Mr. G. W. Fuller, we made a calculation from our data to determine the amount of solids "wet burned." From this calculation it was seen that the total amount of solids in the influent from May 3 to September 3 was 78,300 pounds, while the effluent contained 65,400 pounds and the sludge 8,070 pounds of solids. Adding the sludge solids to those of the effluent and subtracting from the total solids in the influent, we see that there is a loss of approximately 5,000 pounds of solids. In other words, approximately only two-thirds of the solids removed are obtained as sludge. The sludge yield amounts to a little less than one-half ton per 1,000,000 gallons.

Character of Sludge. From the analyses of the sludge given in Table IV its extremely light character can be observed. The average analysis of sixty-four samples of sludge shows 99.74 per cent moisture. The nitrogen in the dry sludge calculated from analyses of wet samples amounted to 5.63 per cent. This, it will be noted, is calculated as nitrogen and not as ammonia.

TABLE IV.

SLUDGE ANALYSES.

(Average of 64 samples)

Moisture	99.74%	
Total solids	2622.	p. p. m.
Total nitrogen	211.8	p. p. m.
Nitrogen in dry sludge	5.63%	

Relation Between Volume and Weight of Sludge. It has generally been the practice[30] to control the amount of sludge in the aerating chamber by withdrawing a sample from time to time and reading the volume to which it settles in a given length of time. Our experience led to the observation that where the sludge was exceedingly light and feathery in appearance, it did not have the same purifying effect as when a denser sludge was employed. In order to determine whether there was any distinct relation between the volume and weight of these settleable solids, we have plotted in the diagram (Fig. 5) the volume against the weight. These points indicate that

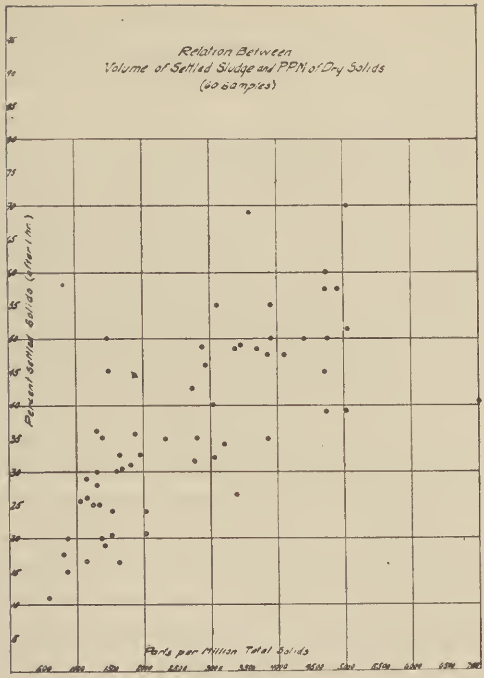


Fig. 5

there is no definite relation between these two values. For example, taking four samples of sludge which settled to 50 per cent by volume, we observe that one contained 1,500 parts per million of dry solids, a second, 3,800 parts per million, a third, 4,400 parts per million, a fourth, 4,750 parts per million. And again taking three samples of sludge which contained approximately 5,000 parts per million of dry solids, we see that one settled to 70 per cent by volume, a second to 52 per cent by volume, and a third to 38 per cent by volume. In a third case two samples settling to 40 per cent by volume showed 3,000 to 7,000 parts per million of dry solids respectively. With as wide and irregular variations as these it is apparent that in our case at least it is impossible to judge the effective amount of sludge by sedimentation. If the variations were only slight it might still be possible to operate using sedimentation, but when the variation becomes so great that the volume figures would indicate opposite procedure to that of the weight figure, it is necessary to change the method of control. For example, during one period of operation the aeration chamber was carrying about 70 per cent by volume of sludge, yet this sludge contained only 1,500 parts per million of dry solids. Judging from the volume, one would have said that too much sludge was

present, but from the weight there was evidently not sufficient sludge present. Instead of drawing sludge, as the volume data would have led us to do, we actually returned sludge to the system, with the result that conditions were improved.

Microbiology of Activated Sludge. In the study of the microbiology of activated sludge in its development from raw sewage there seems to be a definite succession or addition of forms as the sludge develops. Beginning with the characteristic micro-organisms of raw sewage as it is taken into the aeration chamber, there is a predominance of the minute flagellates and ciliates, with occasional Peritrichs and Holotrichs. In a few days the minute forms diminish in number until they become a negligible quantity, while Peritrichs. Holotrichs, and Heterotrichs increase in number, the Peritrichs predominating throughout. As the minute forms become insignificant there appears the zoogleal masses of the Chlamydobacteriaco and Nematodes which are followed in a few days by the sudden appearance of Hypotrichs. This point then brings us to the characteristic fauna and flora of the matured activated sludge, under the particular conditions of operation.

The animal inclusions of the sludge made up a very small part of the entire mass. The base of the sludge was composed of zoogleal masses intermixed largely with filamentous bacteria and occasional zoogleal ramigera.

It appears that the filamentous forms overwhelmingly predominate the sludge. The literature on filamentous forms is scattered and rather uncertain taxonomically. Therefore a more extensive study of these inclusions and the literature on this subject is being made which will determine the species of the forms present. Crenothrix polyspora, sphaerotilus dichotomus and zooglea ramigera were, however, undoubtedly present in large numbers.

Filaments of the type crenothrix are subject to great variation. Perhaps some of the variants deserve the designation of species, but, inasmuch as they are without a doubt due to immediate environmental influences, they should be considered merely as growth habits, at least until isolation in pure culture is accomplished. From the evidence presented sphaerotilus natans appears to be a variant of crenothrix polyspora or at most a species rather than a distinct genus.

Sporelings, short and long, occurred commonly in connection with crenothrix, never in connection with sphaerotilus dichotomus, and, therefore, the latter possibly originates from spores produced by filaments of the crenothrix type.

Herring[31] long ago pointed out the importance of bacterial surface in sewage purification, though little definite data has been com-

piled since his paper on this subject. From the tables we may obtain a notion of the order of magnitude at least of the surface of the activated sludge. Let us take a case (see Table XIV) where two million standard units of zoogleal masses were found per cubic centimeter in the aeration chamber. Each floc must have a lower surface equal at least to the upper surface estimated, so that leaving out the side surfaces we would have four million standard units of 0.0004 mm.sq. each, or 16.0 cm.sq. of surface per cubic centimeter of volume. This figure does not include the surface of the protozoa nor the free-swimming bacteria. If increased by fifty or one hundred per cent it would probably approach more closely the correct value. This would mean approximately 500 sq. ft. of sludge surface per cubic foot of aeration chamber volume.

In view of previous publications of other experimenters cited and the data of the present article we wish to propose the following statement concerning the mechanism of the activated sludge process.

Activated sludge flocs are composed of a synthetic gelatinous matrix, similar to that of Nostoc or Merismopedia, in which filamentous and unicellular bacteria are imbedded and on which various protozoa and some metazoa crawl and feed. The purification is accomplished by ingestion and assimilation of the organic matter in the sewage by organisms, and its resynthesis by them into the living material of the flocs. This process changes organic matter from colloidal and dissolved states of dispersion to a state in which it will settle out.

Mechanical Operation of the Plant. From the description on page 36 in the main body of the report it will be seen that one of the principal features of the Dorr-Peck tank was that during aeration the sewage and sludge were circulated in a path leading up from the aeration chamber and returning through a centrally located cylindrical well.

The second feature of this tank was that the settling chamber was placed above and in communication with the aeration chamber, thus providing for automatic sludge return as was done in the Frank (loc. cit.) tank.

The circulation of sewage and sludge making use of the air lift effect of the aerating air in a tank not complicated by a sedimentation chamber superimposed on the aeration chamber has recently given very good results at Manchester, Indianapolis, Woodstock and Chicago (supra). A method has been devised for determining the rate of circulation and amount of returned air resulting from this circulation. Although originally devised for a circular tank with a central well, it should be

applicable as well to a rectangular tank in which the circulation is over and under a central baffle. The manner of procedure and a description of the necessary equipment for the test is given on page 42. With this apparatus two series of tests have been run. In the first the velocity down the central downcast well was found by current meter readings to be .70 to .75 feet per second, and the "returned air" amounted to 5.1 per cent of the amount introduced through the filtros plates. In the second series the velocity down the central downcast well was .65 to .70 feet per second and the "returned air" 6.3 per cent of that blown. The central downcast well velocity might be expressed by saying that the average particle circulates down this well twenty times.

Purification Results. The operating data and the results of some 15,000 chemical analyses are compiled in a complete series of tables to be found in the appendix. A compact summary, or general average of data from May 3 to September 3, is shown in Table V. It

TABLE V.

AVERAGE ANALYSES OF 234 SAMPLES.

From May 3 to September 3

(Sewage treated: 9,466,000 gallons)

Screened Sewages.

	Maximum	Minimum	Average		Average excluding June 16-July 31*
Settleable solids (1 hr. Imhoff cone)	0.47	0.13	0.26%		0.26
Turbidity	447	129	237		234
Residue on evaporation	1560	840	997	ppm.	1007
Chlorides	195	62	113	ppm.	109
Alkalinity (Methyl Orange)	493	237	420	ppm.	405
Oxygen consumed (from $KMnO_4$ ½ hr. 100°)	103	25	59.3	ppm.	58
Free ammonia	24.6	7.2	16.4	ppm.	15.5
Albuminoid ammonia	11.3	0.9	4.2	ppm.	4.2
Total organic nitrogen	40.0	4.0	12.3	ppm.	12.1
Nitrate nitrogen	14.6	0.1	1.4	ppm.	2.1
Nitrite nitrogen	0.59	0.0	0.15	ppm.	0.26

Effluents

	Average of 234 ssample	Average excluding June 16—July 31*	
Turbidity	68	48	
Residue on evaportion	863	828	ppm.
Chlorides	114	107	ppm.
Alkalinity (Methyl Orange)	405	398	ppm.
Oxygen consumed (From $KMnO_4$ ½ hr. 100°)	35.8	33.0	ppm.
Free ammonia	14.8	15.1	ppm.
Albuminoid ammonia	2.2	1.7	ppm.
Total organic nitrogen	7.9	5.7	ppm.
Nitrate nitrogen	0.69	0.90	ppm.
Nitrite nitrogen	0.10	0.10	ppm.
Relative stability (Methylene Blue)	(2½ days)	43	%

*From June 16 to July 31 sludge was allowed to overflow tank No. 2 with the effluent.

Over shorter periods considerably better results were obtained, as is shown in Table VI.

Here it will be observed that average stabilities of 56 to 87 per cent respectively were obtained.

will be noted that from June 16 to July 31, a light sludge was obtained which was allowed to overflow, the idea being to determine whether this light sludge would continue to form under the conditions of operation, or whether it would gradually increase in density. Leaving out this period, we see that the average turbidity of the influent is 234 p.p.m., while that of the effluent is 48. The oxygen consumed from permanganate is decreased from 58 to 33 p.p.m. while the nitrate is decreased from 2.1 to .90 p.p.m. The relative stability, using the methylene blue test, averages two and a half days or 43 per cent on a ten-day scale. For the purpose of answering frequent inquiries the bacterial count on the raw and treated sewage was determined over a ten-day period. These results indicate in general a 90 to 95 per cent removal of total organisms.

Fig. 6

General Operation. In Fig. 6 we have plotted the different amounts of raw sewage treated, sedimentation periods, aerating periods, amount of air used, and stability from May 3 to September 28.

In this diagram it may be seen that the amount of sewage treated varied from 93,000 gallons per day to 62,000 gallons per day, while the aerating period varied from a little less than seven hours up to a little more than ten hours. The amount of air varied from approximately .7 cu. ft. to 1.41 cu. ft. When compared with the previous diagram it is noted that with high nitrates in the raw sewage, a

flow of approximately 90,000 gallons per day was treated with about .7 cu. ft. of air, and employing a seven hour aeration period, giving at the same time very satisfactory stability results. With a decrease in nitrates, however, it was necessary to increase the amount of air and decrease the flow, so that equally satisfactory results were obtained using approximately a ten hour aeration period and 1.4 cu. ft. of air.

The performance of the Dorr-Peck tank as shown by the above curves indicate several criticisms of the present design. The sedimentation allowed for is, roughly speaking, fifteen gallons per square foot per day and the aeration period is from eight to ten hours. For a large plant the extra tank space required might more than offset what economics might be effected by reason of the lower air consumption.

There were so many adjustments to be made under varying conditions that the operating control of the apparatus was difficult. The rates of flow through the sedimentation chambers, for example, were dependent upon four independent variables.

Shortly after the conclusion of these experiments, the Dorr Company issued a statement[32] to the effect that they had "given up any further work with this process."

The fact should not be overlooked, however, that the circulating feature of the Dorr-Peck tank, as pointed out above, has given considerable promise of successful application when not complicated by a superimposed sedimentation chamber.

Sludge Drying. The description of the experiments in the drying of activated sludge will be found beginning on page 93. The methods tried were (a) acidification and sedimentation, (b) acid heat flotation, (c) Oliver continuous filter, (d) Tolhurst centrifuge, (e) Patterson filter press, (f) Bayley drier.

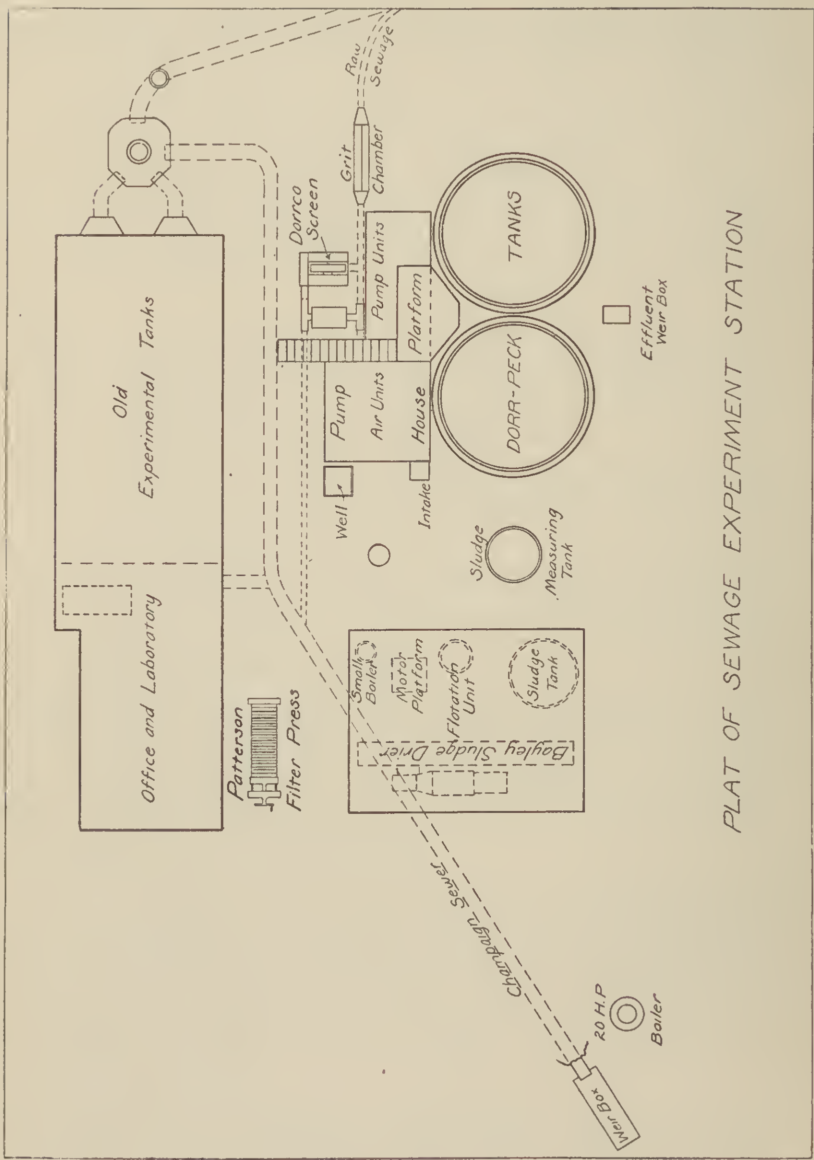
The acidification and sedimentation experiments were carried out for the purpose of demonstrating the advantage of adjusting the reaction to a definite pH (the isoelectric point of the sludge) rather than adding an amount of acid calculated from a titration. This work was first reported in a paper by Buswell and Larson, read December 28, 1920, before Section C of the American Association for the Advancement of Science.

The acid-heat-flotation process operated well, although the estimated cost was in the neighborhood of \$8 to \$12 per ton of dry solids. This is figured on the basis of reducing the moisture from 99 per cent to 85 per cent.

The results on the Oliver filter, centrifuge and filter press were in general negative, due probably to the very light character of the sludge.

The Bayley drier dried floated sludge of 80-85 per cent moisture without odor.

Fig. 7


Raw Sewage
Grit Chamber
Dorrco Screen
Pump Units
Platform
TANKS
DORR-PECK
Effluent Weir Box
Old Experimental Tanks
Pump
Air Units
House
Well
Intake
Sludge Measuring Tank
Office and Laboratory
Patterson Filter Press
Small Boiler
Motor Platform
Flotation Unit
Sludge Tank
Bayley Sludge Drier
Champaign Sewer
20 H.P Boiler
Weir Box
PLAT OF SEWAGE EXPERIMENT STATION

CHAPTER II.

DESCRIPTION OF SEWAGE EXPERIMENT STATION 1920-21.

By A. A. Brensky.

The site chosen for the location of the Sewage Experiment Station was adjacent to the old septic tank, where the second series of experiments had been conducted. The situation of the station was excellent, except that it was two and a half miles from the Water Survey laboratories, and in bad weather, the roads were difficult to travel. Construction of the main plant was carried on from April to November, 1920, and the equipment for dewatering of sludge was added during the period of operation, December, 1920, to January, 1921.

The Sewage Experiment Station is made up of two parts, namely: (1) the plant proper, where the sewage undergoes purification, (2) the sludge drying equipment. These will be described in order. Fig. 7 shows the general arrangement.

The plant is composed of a grit chamber, a Dorrco screen, a pump pit, two Dorr-Peck tanks equipped with Dorr thickeners, apparatus for measurement of air and sewage, air blower, the necessary pumps, motors, and other accessories.

Fig. 8 shows a flow sheet diagram of sewage and air through the plant. Sewage flows from the main sewer by gravity through the grit chamber to the Dorrco screen, where part of it can be by-passed either to the pump pit or to the sewer. The screened sewage flows from the Dorrco screen into the pump pit or sewer. From the pit the sewage is pumped into the bottom of the first Dorr-Peck tank, where overflowing the periphery at the top, it flows into the bottom of the second tank from which the effluent and sludge is discharged.

Grit Chamber. A representative fraction of the sewage flow was secured by tapping the Champaign sewer with an eight inch pipe two inches above the invert of the sewer and at an angle of 40° with the direction of flow. The eight inch pipe had a carrying capacity of 400,000 gallons per day, which entered the grit chamber by gravity. This chamber consists of two parallel channels ten feet long and eleven inches wide, with gates at the end of each channel. The bottom of the chamber is three inches below the invert of the

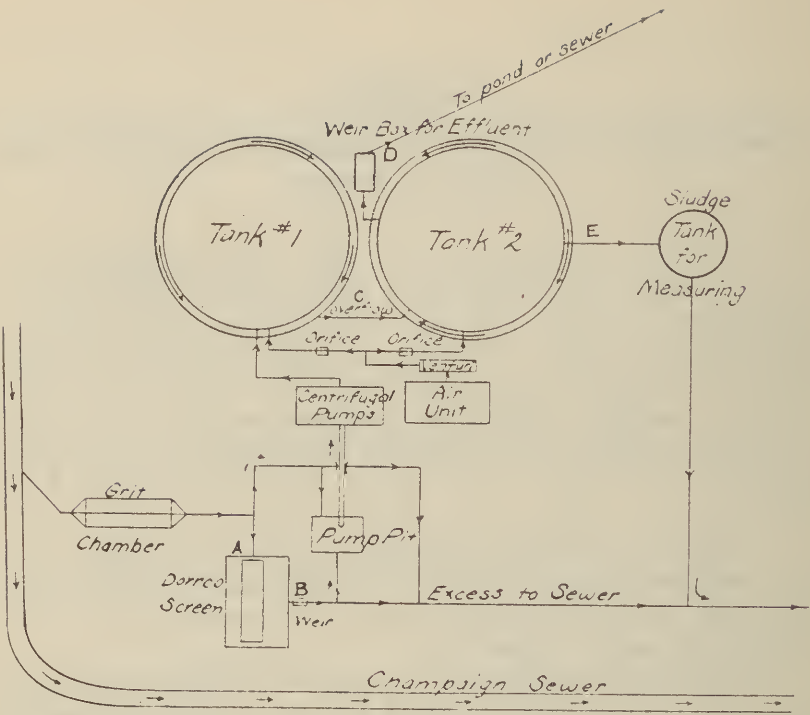


Fig. 8

eight inch pipe. Usually one chamber was used at a time, when a velocity of flow of one foot per second was maintained. In order to protect the Dorrco screen against large objects, the inlet of each channel was provided with a vertical bar screen having a one inch opening.

Dorrco Screen. Figure 9 shows some of the essential features of the Dorrco screen. This screen consists of a revolving drum, four feet eight inches in diameter, the periphery of which is covered with a screen having slots one-sixteenth of an inch by one-half inch parallel to the axis of rotation. In one of the drum heads there is a concentric circular opening, eighteen inches in diameter, into which a steel pulley is set which forms the outlet, and at the same time supports the head of the drum upon the rotating shaft. The periphery of the steel pulley projects one inch beyond the drum head and rests in a semi-circular opening between the raw sewage and screened sewage compartments. Between the opening and the pulley a piece of cloth belting forms with the aid of the collected solids a water tight joint between these compartments. Practically no friction is caused by the pulley in revolving with the drum.

Fig. 9

A portion of the sewage which passes through the grit chamber flows by gravity into one end of the screen compartment at an elevation, three inches below the rotating shaft of the drum. As the submerged screen moved down with the inflowing sewage, the solids were collected on the submerged surface of the drum, while the screened sewage flowed inward through the perforations and thence through the eighteen inch outlet into the stilling chamber. The rotating screen carried the screenings collected on its surface to the sewage level just opposite the inlet. The rotating motion of the screen builds up a few inches of head inside of the screen drum. At this point the back washing cleaned the screen and discharged the screenings into the pit. A piece of wood eight inches long, two inches wide and one-half inch thick was nailed to the surface of the screen to assist in the removal of the solids from the surface and in depositing them in the pit. The screened sewage was measured through a twelve inch rectangular weir as it left the screen wheel and the screenings were collected from the chamber pit and weighed.

Pump Pit. A pump pit three feet by four feet and four feet in depth was made of concrete six inches thick. It was designed to admit either screened or unscreened sewage.

Dorr-Peck Tanks. Briefly, a Dorr-Peck tank may be described as a two-story tank in which the process of aeration, the process of sedimentation and the automatic return of activated sludge to the incoming sewage is performed in a single tank. To accomplish this, each tank is divided into two compartments by a steel partition built to resemble an inverted funnel (Fig. 10). In the upper annular chamber sedimentation takes place; the lower is used as an aeration chamber. The cylindrical portion of the partition which extends upward through the settling chamber forms a well three feet in diameter known as the upcast well; its conical portion is called the tray. Four wells, six feet long, six inches wide, called peripheral downcast wells, are welded to the periphery of the tray so as to follow the curvature of the tanks. They extend downward through the aeration chamber, terminating in four baffle boxes, each eight feet long and twelve inches wide. These baffle boxes are nailed to the sides of the tank, eighteen inches above the bottom. The tray is supported by a six inch wooden shelf along the periphery of the tank between the periphery downcast wells. Two tanks similar in design but differing in the relative size of aeration and sedimentation chamber were operated in series. The height of the shelf is eight feet in the first tank and seven feet in the second, thus giving the aeration

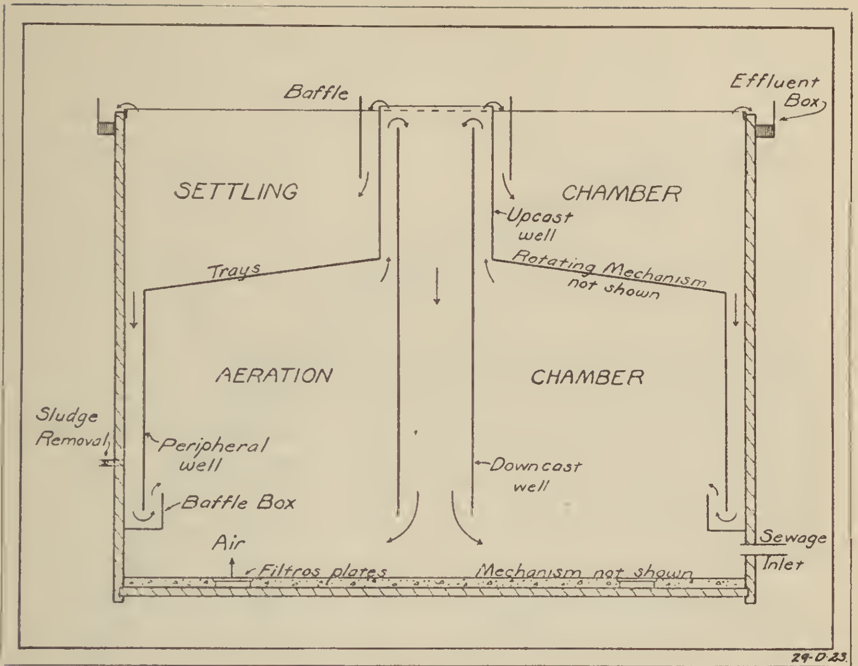


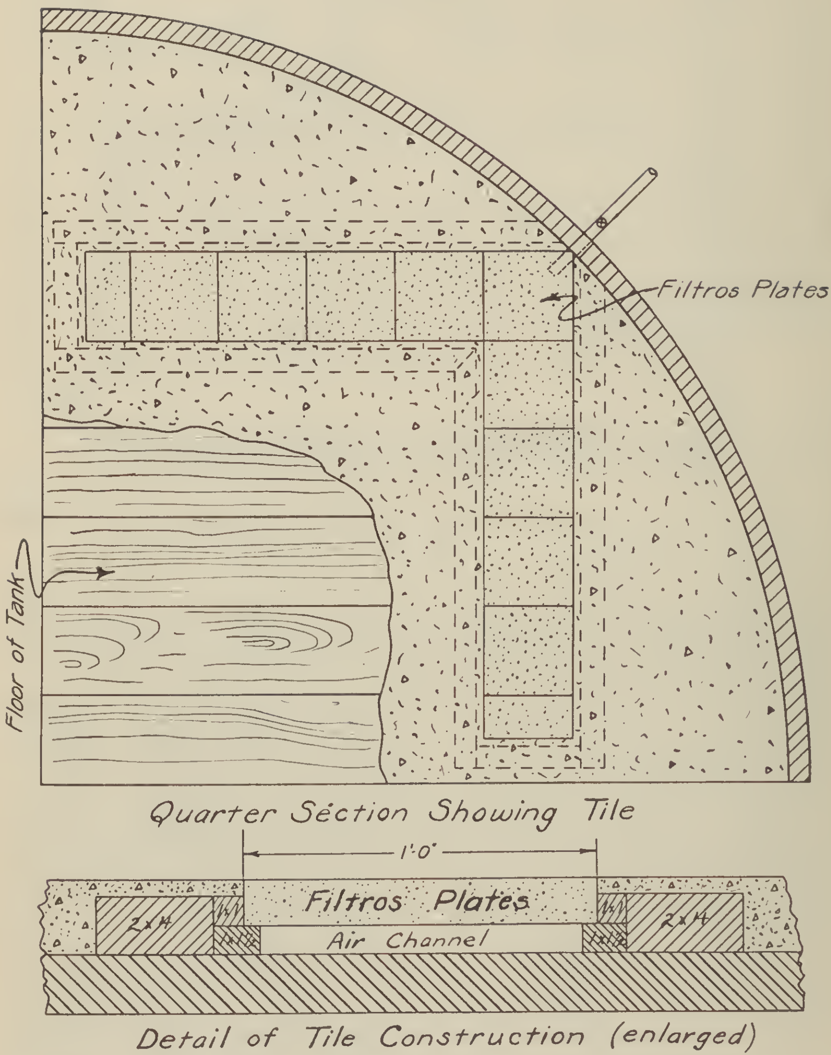
Fig. 10

chambers a relative capacity equal to 14,400 gallons and 13,700 gallons, respectively, and leaving for the sedimentation chambers 7.600 gallons and 9,300 gallons, respectively. Within the upcast well, a two-foot hollow steel cylinder or ''central downcast well'' extends from within a few inches below the upcast well to within eighteen inches of the bottom of the tank. This well is supported on the central shaft of the mechanism for operating the thickeners. (For a description of the latter see below.) Bands of six-inch rubber belting attached to the tops of the upcast and downcast wells serve as adjusting collars for distributing the flow and regulating the circulation in the tank.

An annular trough, six inches wide, made of laminated strips of wood was nailed around the top of the tank to collect the overflow from the settling chamber. A leveling board is placed around the periphery of the tank to secure equal distribution of the overflow from the surface.

A set of forty filtros plates was laid in the bottom of each tank in the form of an inscribed square and had an effective area of 17 per cent of the bottom. Each set of plates was divided into four

Fig. 11


Filtros Plates
Floor of Tank
Quarter Section Showing Tile
1'-0"
Filtros Plates
2x4
2x4
Air Channel
Detail of Tile Construction (enlarged)

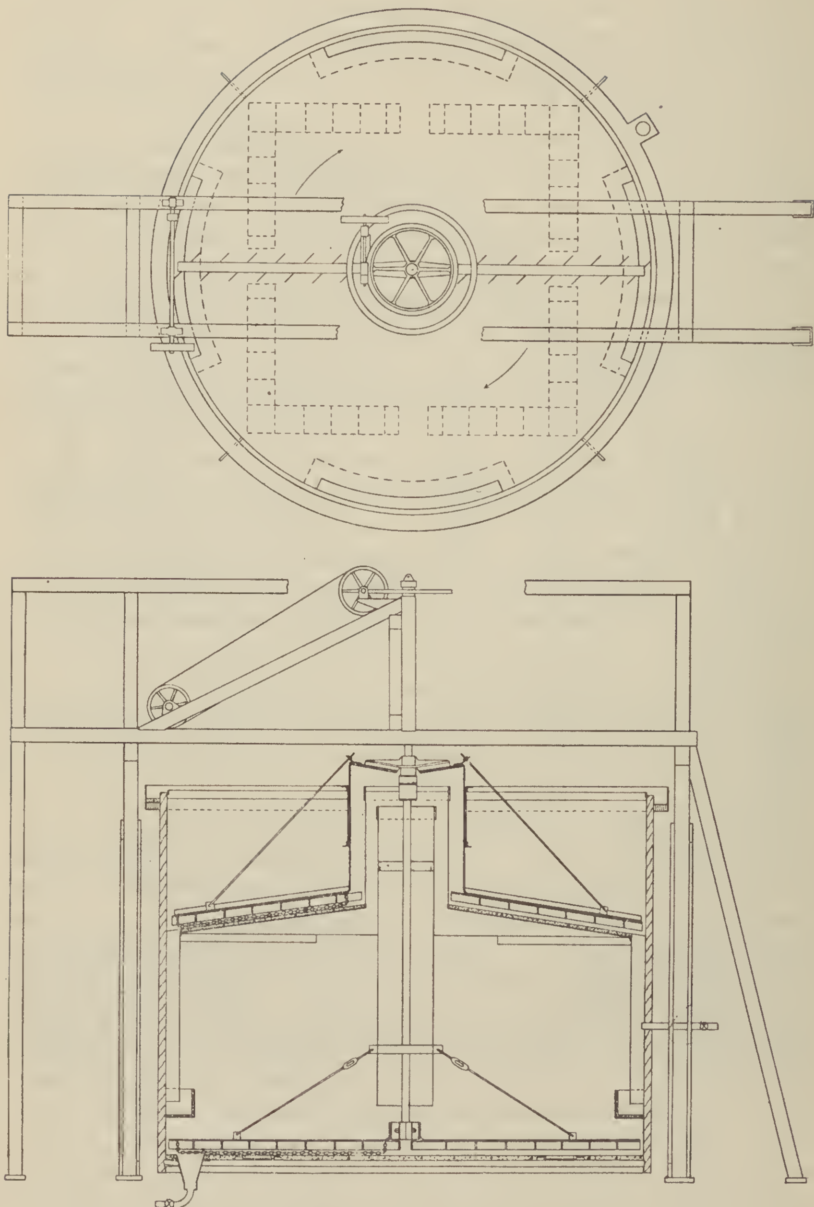
independent sections of ten plates with inlets at each corner of the square. Figure 11 shows the plan and section of a set of a quadrant of the system of plates. Air could be shut off from any section by a valve without interrupting the operation of the tanks. The filtros plates were of Grade E manufactured by the General Filtration Company of Rochester, N. Y.

Dorr thickeners, modifications of the original continuous thickeners made by the Dorr Company for use in the concentration of metallurgical slimes and pulps, were installed in each tank. Each consists of a slow-moving worm gear keyed to a central vertical shaft supporting two sets of radial arms. Each set of arms was equipped with steel blades, three inches by twelve inches, set at such an angle that in clockwise rotation they would plow or rake outwardly. One set of arms located above the tray is suspended from a spider clamped to the shaft; the other set is clamped to the bottom of the shaft and is hung just above the filtros plates. The rakes are supported by tie-rods and the height of the ends above the tray and plates are adjusted by turn-buckles. A baffle four feet in diameter and three feet in depth is attached to the vertical members which support the upper rakes. This baffle and the central downcast well rotate with the mechanism. Scouring chains are attached to the upper and lower rakes. The entire mechanism is supported by a super-structure built independently. Figure 12 shows part of the structure.

The sludge settling on the tray is mechanically thickened and pushed to the wells by the revolving rakes and chains. The function of the mechanism in the lower chamber is to prevent the collection of sludge upon the bottom of the tank.

Sewage enters the first tank, as indicated (See Fig. 10) by the arrow in the lower right. It is mixed with sludge returning through the peripheral downcast wells, and aerated. The air bubbles, acting as an air lift, cause the sewage to rise to the level of the top of the upcast well and overflow. A portion of the aerated sewage then slops over the collar of the upcast well and passes through the sedimentation chamber, while another portion returns, together with considerable amounts of air, through the central downcast well. This central downcast well has an effect somewhat similar to the down suction wells of the Brosius and Trent machines, with the result that air is drawn down with the returning sewage. The effluent from the first tank passes by gravity to the bottom of the second tank, which is set a little lower to provide the necessary head. The amount of liquid slopping over the collar of the upcast well must be greater than the total flow of sewage, otherwise sewage would pass up the peripheral

Fig. 12



downcast wells, a condition which must be absolutely prevented. The amount of the slopover has been measured by means of a weir shown in Figure 13.

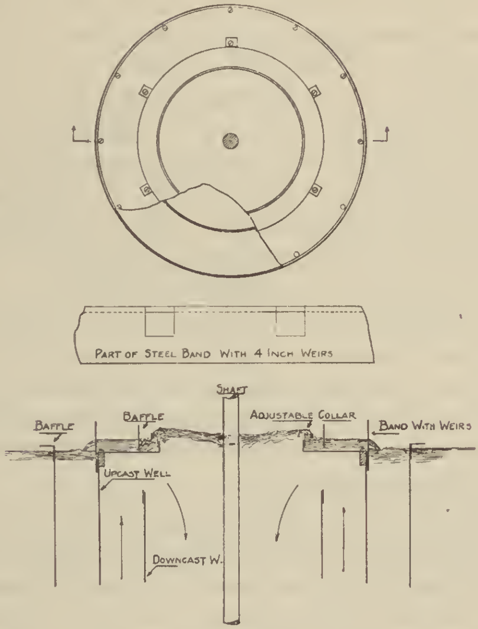


Fig. 13

The outer circle shows a metal outer wall band with weirs which is clamped around the upcast well. The second circle shows a stilling baffle, while a third circle, not seen in this view, represents the collar of the upcast well. The cross-section shows the flow through the weir. Figure 14 is made from a photograph of the weir in operation. The sewage which is raised by the air lift slops over into this annular

Fig. 14

weir instead of directly into the sedimentation chamber. By means of this device we are able to measure the rate of flow in the sedimentation chamber. The weir is provided with an inner movable collar, the adjustment of which determines the amount of the slopover. The effect of this adjustment may perhaps be illustrated by mentioning one or two critical points. If, with a constant flow of sewage and air, the collar is adjusted so that the flow through the weir is just equal to the total flow of sewage, we have the highest operating position of the collar, and at the same time a minimum velocity in the sedimentation chamber and a zero velocity down the peripheral downcast wells. When from this position the collar is lowered the flow is increased through the weir, thereby increasing the velocity in the sedimentation chamber and producing an appreciable velocity down the peripheral downcast wells. Incidentally, it might be noted at this point that the velocity in the sedimentation chamber and the amount of return of sludge through the peripheral downcast wells are dependent upon the same adjustment, namely, the height of the collar on the upcast well weir. This same effect can be obtained by lowering or raising the downcast well.

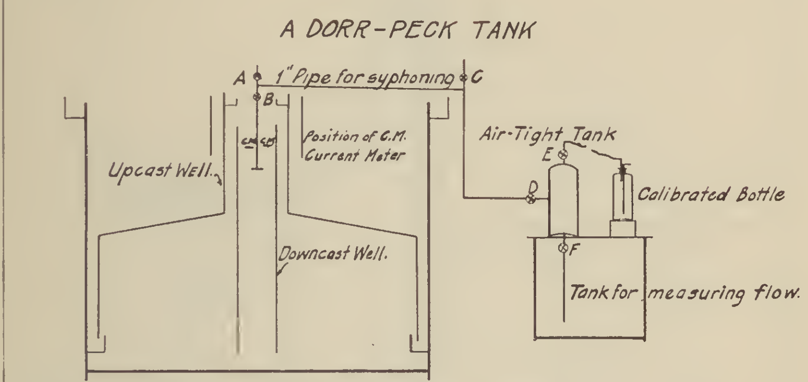
If, again starting from the position at which the flow through the weir is exactly equal to the pumpage, we should raise the collar of the upcast well weir, we would cause a reversal of the flow through the peripheral downcast wells, thereby disturbing sedimentation and preventing the return of sludge to the aerating chamber. An additional adjustment was provided by placing a movable collar around the upper end of the central downcast well, with the idea that raising this collar would decrease the amount of return through this well, and lowering, of course, would have the opposite effect. The adjustment of this apparatus was sufficiently complicated without the use of this collar, so that we have made practically no use of it.

It will be seen, then, that there are four factors effecting the rate of flow through the sedimentation chamber: First, the amount of sewage pumped; second, the amount of air used; third, the height of the collar on the upcast well or weir; and fourth, the height of the collar on the downcast well. To maintain the sedimentation chamber velocity constant, it is necessary, therefore, to adjust the collar for each change in amount of sewage treated or amount of air used.

The air economy accomplished by this apparatus is presumably due, in a large measure at least, to the return of air and sewage through the central downcast well.

The degree of the circulation depends upon the difference in density of the mixtures of air, sewage, and sludge in the aeration

chamber and the downcast well. The quantity of minute entrained air bubbles, returning with the liquid, depends upon the velocity of the circulating liquid.



A DIAGRAMATIC SKETCH OF ARRANGEMENT OF SET-UP USED FOR MEASURING RETURNING AIR & SLUDGE IN CENTRAL Downcast Well.

1 With valve F closed, the pipe line & tank are completely filled with liquor until it is discharged at E. Close E and reprime at A, displacing all of the air in the system.
2. Open Valve F; A portion of the mixture in D.C. well flows into Air light tank when air is trapped while liquor flows into measuring tank below. Allow to run for a period of time
3. Close Valves F, then D. Open C, to break siphon, then D. Attach tube at E to bottle. By opening E, and pouring water into pipe at C, air in the tank displaces equal volume of water.

Fig. 15

Figure 15 shows an arrangement of apparatus used for determining quantitative results on the rates of "returned air" to the circulating liquid. The manner of procedure in performing the tests may be seen from the figure. Two series of tests were run. The data collected is appended and the summary given below. The velocity in the central downcast well was found by a series of current meter readings to average between .70 and .75 feet per second in the first test, and .65 and .70 feet per second in the second test; the volume of "returned air" was 5.1 per cent and 6.3 per cent respectively of the air introduced through the filtros tile. The circulation is best expressed by saying that the average particles circulated about fifteen times before passing into the settling chamber. While the data collected in this manner is consistent, there is no assurance that it is not subject to a constant error. This somewhat cumbersome apparatus had to be installed without interrupting operation. A new arrangement of apparatus was made (Fig. 16); it was not used, however, for checking the above results. Again the sludge drawn through the pipe was filled with minute bubbles of air. It was thought that by entirely

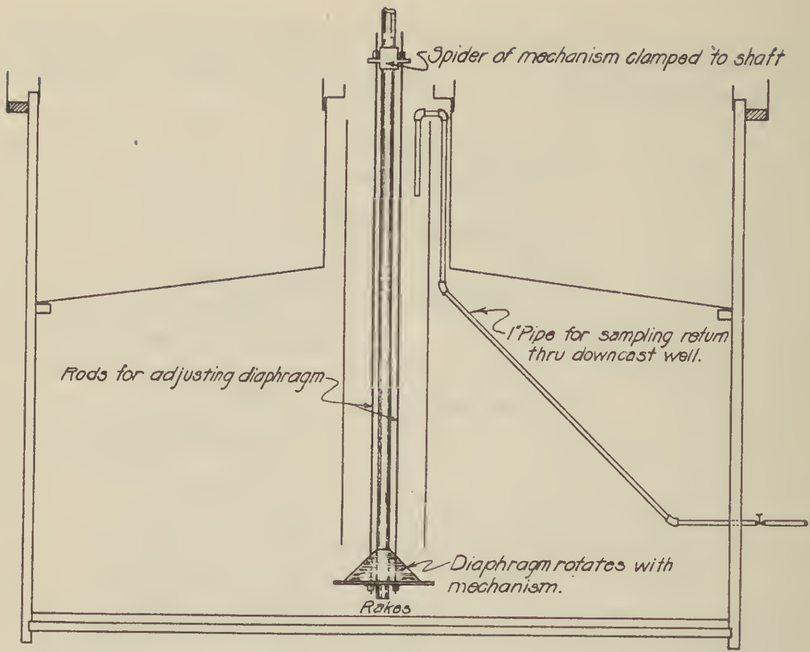


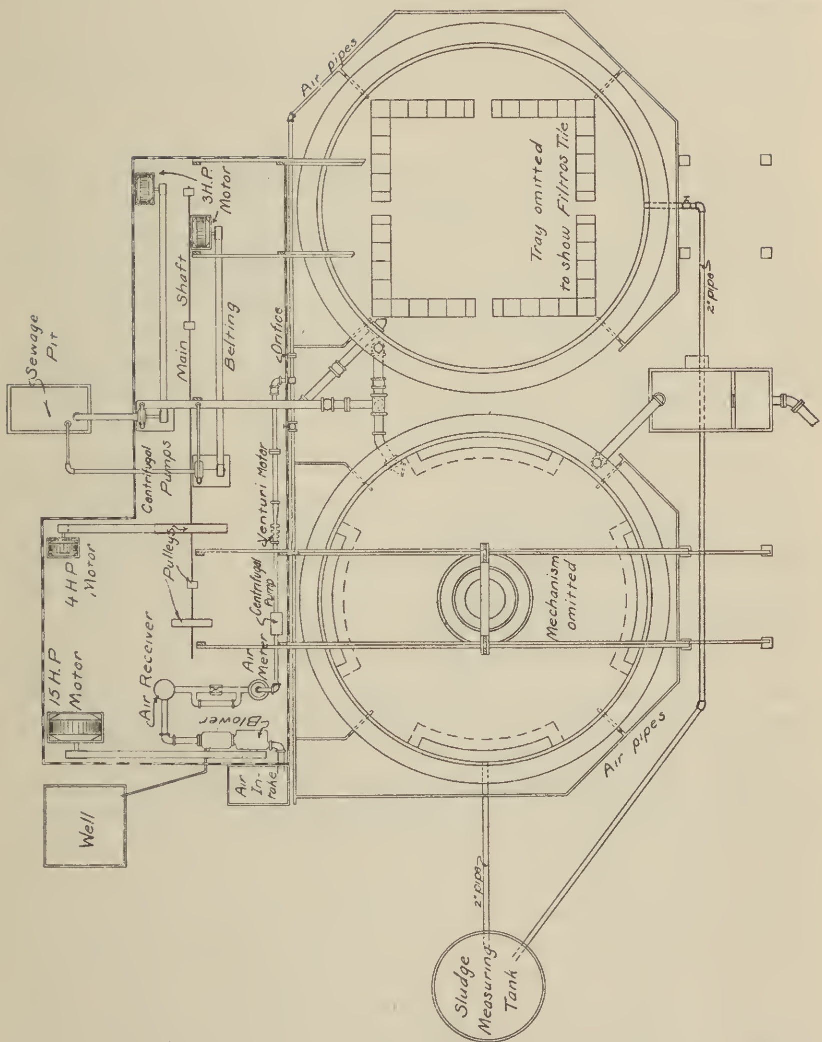
Fig. 16

closing the well by raising the diaphragm (Fig. 16) there would occur a great increase of flow into the settling chamber, but the increased head (difference between collars was from eight to ten inches) greatly effected this quantity. Measurements taken on tank No. 2 with the downcast well closed and a flow of air of twenty-eight cubic feet per minute caused a flow two to three times that resulting from the apparatus with a fully opened well. This arrangement was effective in adjusting the flow to the sedimentation tank and did away with collar adjustments.

Blower and Pumping Equipment. Figure 17 shows the plan of the one story frame building and the general layout of the sewage pumping units, air unit, line shaft, apparatus for air flow measurements, etc. The building served as bracing for the east ends of the superstructure of the tank mechanism and supports an observation platform upon its roof. Adjacent to the north end, is the air intake to the blower and also a dug well, four feet square, nine feet deep, lined and braced with two-inch lumber. The well is used to supply water for various purposes, including the cooling of the compressor.

Two units were used for pumping sewage from the pump pit to the tanks. The larger unit was a Morris centrifugal pump, with three inches suction and two inches discharge. The smaller unit was an

Fig. 17


Air pipes
Tray omitted
to show Filtros Tile
3H.P.
Motor
Main Shaft
Belting
Orifice
Sewage
Pit
2" pipe
Centrifugal
Pumps
Venturi Motor
Pulleys
4 H P
Motor
Centrifugal
Pump
Mechanism
omitted
15 H.P
Motor
Air Receiver
Air
Meter
Blower
Air pipes
Air
In-
take
Well
2" pipe
Sludge
Measuring
Tank

American centrifugal pump, with a two inch suction, and a one and a half inch discharge. In each case the belt was connected to a 3 h.p. motor. The capacity of the pump was 110 and 70 gallons per minute respectively. The suction pipes were equipped with foot valves and the pumps were primed by the back flow from the tanks. Both pumps discharged into a four inch cast iron pipe leading to tank No. 1. The piping was arranged so as to use either tank separately. The center lines of the pump were three and a half feet above the average sewage level in the suction pit and twelve and a half feet below the water level in the first tank.

A six inch rectangular weir measured the sewage after passing through the tanks. The weir was set in a wooden box six by two feet, and three feet deep, from which the effluent discharged into a four inch pipe leading to the pond or sewer. The sewage flow was regulated by a hand operated valve and by changing the speed of the pumps. The large pump with a speed of 450 revolutions per minute discharged from fifty to sixty gallons per minute. The large pumping unit was operated over ninety per cent of the time, and on the whole gave very satisfactory service. The smaller unit was held in reserve.

Air was supplied by a Nash Hydro-turbine blower with a rated capacity of ninety cubic feet of free air per minute, manufactured by the Nash Engineering Company of Norfolk, Conn. It was belt-connected to a 15 h.p. motor which happened to be available, though so large a motor was not required. The air to the blower was filtered through two wire boxes covered with a layer of No. 10 oz. duck and a layer of canton flannel respectively, and washed by the circulating water through the hydro-turbine blower. This water (less than 1 g.p.m.) is necessary to the operation of the blower and at the same time serves as cooling water. The discharge from the blower is a mixture of air and water which separates in a dewatering baffle box, the water returning to the well and the air discharging into the bottom of a galvanized iron air receiver one foot in diameter by two and a half feet in depth, where further entrained moisture is removed. A Ross constant pressure valve was placed in the air line, but arrangement was made to by-pass it. The air passed through a Rotary air meter into a four inch cast iron pipe equipped with a four inch by two inch Venturi meter and a one and a fourth inch orifice meter. Between the tanks the line divided into two three inch supply lines, distributing the air through one and one-half inch pipes to the inlets of the filtros sections. The inlets were reduced to one inch pipes and controlled by a one inch globe valve.

The volume of air discharged from the blower was changed by

varying the speed of the hydro-turbine. When using a nine inch pulley, the blower speed was 1100 revolutions per minute, and the discharge was from seventy-eight to eighty cubic feet per minute against a pressure of 6.75 pounds per square inch; and with a ten inch pulley attached to the blower, the speed of the blower was 920 revolutions per minute and delivered from 60 to 65 cubic feet per minute. The volume of air admitted to the tanks was regulated by a waste air valve, and the proportion to each tank was regulated by a three inch valve.

A line shaft, twenty-four feet long, was driven by a 4 h.p. motor and furnished power for the mechanism of the Dorr thickeners, the Dorrco screen, and the Gould centrifugal pump. The pump had a capacity of twenty-five gallons per minute and was used for supplying water to the hydro-turbine blower, as well as for general purposes.

Another one story frame building, constructed in 1916 for former experiments, served as an office, tool and work room. Some of the machinery used in the sludge drying experiments described elsewhere in this report was kept in this building. The old Champaign septic tank in which the first continuous flow activated sludge experiments were made, was employed for storage of lumber, pulleys, and various materials.

A single phase electric circuit from the Urbana Light, Heat and Power Company was reduced by transformers at the plant from 2200 volts to 220 volts and furnished power for the motors and lighting. A separate electric meter was installed for power furnished to the motors in the pump house. A telephone connection was maintained from May, 1919, to January, 1922.

Sludge Dewatering Equipment. The equipment and apparatus used in drying experiments by centrifuging, pressing, acid-heat-flotation, and by indirect drying are described under the various methods employed in Chapter VII under sludge drying experiments.

CHAPTER III.

CHAMPAIGN SEWAGE.

By A. A. Brensky.

General Characteristics. The sewage from the city of Champaign may be described as an ordinary domestic sewage practically free from industrial wastes and receiving abnormally large quantities of ground water in the wet seasons. The largest local producer of liquid wastes is the gas plant, but the discharge of these wastes was stopped when the activated sludge plant commenced operation. Other large contributors of liquid wastes are the laundries and ice cream manufacturers. The sewage from the city travels over 10,000 feet before reaching the outlet. It would be generally considered a fresh sewage, although during part of July and August, 1921, putrescible odors were present in the vicinity of the outlet. As a rule, the strongest sewage reached the outlet from 11 a.m. to 2 p.m., and the weakest sewage from 4 a.m. to 7 a.m. During the latter period the sewage was largely infiltration of ground water. Large amounts of debris, rags, vegetable and animal matter, were present in the day sewage.

Volume of Flow. Measurements of the flow from the Champaign sewer were made hourly during the days in which the plant was in operation. A weir box ten feet long, three feet deep and thirty inches wide, equipped with an eighteen inch rectangular weir was installed at the outlet of the sewer. Accurate readings were difficult to make, due to the drop at the outlet. Nevertheless, the readings are fairly accurate for rates of flow less than 2,000,000 gallons per day. Flows over this amount are probably too low.

The measurements show only the volume of sewage that reached the outlet. At times of high rainfall the sewage flows at full capacity and with a rise in sewage level; an increasing part by-passes to the Boneyard stream in the city. The total flow does not always reach the outlet. When the flow is more than 2,000,000 gallons per day, the sewage flows under pressure, and the rate of flow at the outlet increases very slowly due to the by-passing.

Table VI gives the mean, maximum and minimum of daily sewage flow from January to December, 1921, for days in which the plant was in operation. The mean flow is an average of twenty-four hourly

TABLE VI.

STATE WATER SURVEY DIVISION—SEWAGE EXPERIMENT STATION
URBANA, ILLINOIS

CHAMPAIGN DAILY SEWAGE FLOW IN 1000-GALLON UNITS FROM JAN.-DEC., 1921.

Measurements were taken at outlet. Mean flow is an average of 24 readings taken every hour. Max. and min. rates of flow are based on hourly readings. Formula—Q—3.33(L—0.1H)(H)3-2.

	January				February				March			
	Mean	Max.	Min.	Rfl	Mean	Max.	Min.	Rfl.	Mean	Max.	Min.	Rfl.
1	1315	1810	830	.02	1170	1537	817		1249	1447	910	
2	1017	1270	710		1164	1467	817		1110	1577	665	.35
3	1148	1376	680		1120	1397	657		1100	1400	650	
4	1110	1480	650		1129	1397	817	.15	1123	1400	763	
5	1096	1480	600		1263	1467	817		1127	1420	763	
6	1121	1410	710		1114	1397	904		1134	1455	763	.08
7	1131	1407	650	.17	1301	1687	867	.28	1358	1540	937	.42
8	1093	1473	593		1344	1687	937	.05	1719	2110	1190	.41
9	980	1330	596		1367	1757	867		1616	1900	1180	.41
10	1030	1340	600		1278	1617	817		1600	2080	1180	
11	1058	1510	596		1221	1687	817		1723	2200	1300	
12	1009	1336	575		1197	1500	815		2164	2300	1900	.90
13	956	1410	550	.12	1112	1467	757		2112	2190	1900	.10
14	1010	1340	575		1194	1467	757		2068	2240	1830	
15	1040	1343	603	.01	1281	1467	757		2041	2240	1590	
16	910	1191	516		1149	1502	697		1911	2225	1540	
17	1002	1282	528		1081	1467	637		1716	2020	1290	
18	983	1315	524		1100	1467	697		1801	2080	1540	
19	1002	1350	500		1114	1537	697		1833	2120	1330	
20	982	1300	450	.02	1038	1432	697		1728	2040	1420	
21	1130	1382	717	.28	1151	1577	697		1650	1960	1200	.55
22	1174	1530	692	.20	1162	1537	697	.01	1663	2020	1200	.02
23	1026	1398	670		1138	1502	670		1630	2080	1330	
24	1127	1502	612		1113	1502	697		1989	2040	1900	.79
25	1100	1468	697	.02	1104	1397	697		2031	2040	1900	.22
26	1064	1432	637	.10	1096	1502	697		2025	2080	1750	.34
27	1022	1255	587		991	1327	697		2071	2150	1750	.62
28	1052	1397	613		1084	1432	637		1847	2000	1780	.70
29	1138	1537	781	.10					1907	2000	1900	
30	1173	1257	907	.55					1901	1960	1600	
31	1268	1537	867	.01					1948	1920	1600	

	April				May				June			
	Mean	Max.	Min.	Rfl.	Mean	Max.	Min.	Rfl.	Mean	Max.	Min.	Rfl.
1	1802	1920	1140						2131	2200	2060	
2	1841	1920	1390					10	2056	2205	1660	.42
3	1881	1920	1830						1900	2250	1530	
4	1930	1960	1850		2191	2250	2160		1778	2100	1380	
5	1924	1960	1780		2207	2350	2120		1630	2080	1275	
6	1883	1980	1780	.23	2091	2350	1740		1660	2030	1240	
7					1995	2170	1760		1580	1910	1100	
8					1898	2160	1430		1392	1750	820	.03
9					1909	2100	1330		1370	1710	730	.02
10					1764	2070	1190	.03	1290	1635	730	.18
11					1635	2020	1095	.28	1282	2035	670	.13
12					1560	1956	937	.01	1103	1670	790	
13					1358	1760	848	.07	1121	1490	670	
14					1430	2040	880		1136	1670	670	
15					1230	1620	880		1145	1670	610	.01
16					1307	1730	815		1219	1450	695	.67
17					1277	1680	815		1040	1500	575	
18					1284	1750	815		1002	1400	675	.01
19					1310	1750	725		900	1275	575	.01
20					1330	1750	725		1182	1400	800	.10
21					1260	1750	670		1057	1480	580	.01
22					1043	1520	660		1042	1400	630	.40
23					1164	1620	670		1045	1350	650	
24					1468	1660	730		994	1330	570	.03
25					2150	2600	1300	1.10	945	1220	530	.02
26					2544	2700	2350	3.60	802	1150	575	
27					2453	2580	2300	.06	959	1900	575	.13
28					2185	2300	2000	.01	990	1320	520	.11
29					2082	2200	2000		925	1300	570	
30					2117	2250	2000		850	1150	420	
31					2130	2200	2060					

Plant not in operation.

End of first run—April 7, 1921.

TABLE VI—Continued.

	July				August				September				October				November				December			
	Mean	Max.	Min.	Rfl.	Mean	Max.	Min.	Rfl.	Mean	Max.	Min.	Rfl.	Mean	Max.	Min.	Rfl.	Mean	Max.	Min.	Rfl.	Mean	Max.	Min.	Rfl.
1	886	1200	405		972	1211	714	18	819	1180	394		1125	1450	525	T					2087	2320	1750	.07
2	956	2074	424	.08	1050	1604	484	1.01	1107	2930	644	T	941	1310	475						1911	2140	1275	.24
3	757	921	479		899	1244	527	.01	1623	2620	1035	1.07	1087	1565	525						1711	1850	1410	
4	752	1010	462		779	1157	474		1263	1900	790	1.23	1059	1635	500						1785	1910	1600	.01
5	857	1110	462	.26	740	997	446		1221	1810	915	.50	1038	1520	500						1842	2050	1550	T
6	1195	2376	484	.07	824	1308	369		1083	1480	675		1070	1400	700	T					1701	1950	1330	
7	976	1757	684	T	680	994	424		1109	1430	570		1484	2385	550	.78					1980	2350	1440	
8	1046	1296	583	.26	813	1154	443		940	1370	565		1323	2160	620	T					1818	2205	1040	
9	867	1226	467		843	1091	418		923	1230	515	T	1036	1640	550						1908	2350	1320	
10	755	1001	491		941	2211	465	.21	906	1300	500	.01	1137	1530	540						1741	1990	1310	
11	865	1169	467		1377	2297	663	1.54	787	1110	520	.06	1132	1600	500	T					1568	1870	1170	
12	856	1110	390		1002	1375	518		939	1370	520	.05	1086	1570	450						1590	1830	1200	T
13	827	1110	400		1076	1818	524	.19	954	1340	515		1093	1550	510						1607	1800	1210	
14	877	1140	438	T	738	1108	468	.01	929	1380	500		1156	1565	550						1420	1750	880	
15	790	1056	460		879	1321	471		892	1360	475		1090	1430	500	T					—	1500	930	
16	814	1426	458		790	1170	468		1238	2450	550	.77	938	1240	475	.03				.95	1384	1750	1040	.02
17	761	1024	460		825	1314	418	.13	1114	1740	525		1218	1540	700		1556	2300	1020	.03	—	1600	—	.69
18	1152	2159	517	.92	698	1178	418		950	1310	525		1452	2080	760	.28	2252	2400	1830	2.25	—	—	—	T
19	852	1166	460	—	793	1190	421		1108	1970	550	.30	1498	1990	760	.02	2302	2400	2250	.84				
20	814	1161	460		728	1600	393		1227	1700	790	T	1614	2120	525		2229	2325	2205					
21	818	1124	460		622	980	368		1117	1750	550	.29	1093	1415	525		2008	2250	1910					
22	818	1131	441		858	1150	460		1099	1710	500		1171	1560	500		1976	2160	1890					
23	818	1119	434		957	1680	480	.97	1057	1520	540		959	1240	500		1932	2120	1830	.01				
24	685	881	441	T	953	1330	430		1272	1530	790	T	1089	1565	510		1929	2120	1830	.10				
25	841	1180	424		916	1300	465		1020	1425	525	.66	1042	1500	475		2181	2275	1990	T				
26	833	1160	448		921	1270	413		1086	1530	500		1215	2040	475		2239	2500	2160	.04				
27	1140	1347	474		915	1370	418	.01	1070	1550	525		1095	1580	475	.49	2195	2350	2120					
28	1100	2314	574	.35	860	1300	418		1033	1720	550		1216	1650	780	T	2244	2400	2080					
29	943	1344	474	.92	839	1300	390		1319	1710	730	T	1340	1890	640	.56	2194	2400	1950					
30	880	1351	477	.01	838	1170	413		1238	1635	670	.60	1115	1415	540	.05	2243	2400	2080	T				
31	711	1041	456		857	1140	390	.10					1065	1730	500	.02								

T—Trace of Rainfall.

readings taken from 9 a.m. of one day to 9 a.m. of the following day. The maximum and minimum are based on the largest and smallest hourly rate of flow respectively. A column for the daily rainfall is also given in the table. It shows the effect of rainfall upon the quantities of flow in the sewer.

Averages of the hourly variations in the flow were computed for twelve selected weeks and are tabulated in Table VII. The early morning flow from 4 to 6 a.m. during the spring contains large quantities of ground water, probably as much as 400,000 gallons per day or 20 per cent of the mean daily flow. From July 2 to August 23 the minimum volume of sewage was discharged at the outlet. A comparison between the week of August 16-23 and September 22-29 shows at a glance the effect of a heavy rainfall. The months of November and December were fairly wet periods. The maximum rate of flow for the record kept was during the week of November 17 to 23. A few typical days were selected to show the variation of the hourly flow during the seasons. These are tabulated in Table VIII. With the exception of times of heavy rainfall the maximum rates of flow are two to three times greater than the minimum rates.

TABLE VII.

WEEKLY AVERAGES OF HOURLY FLOW IN THE CHAMPAIGN SEWER.

Unit Rate given in 1,000-Gal. per hour.

Day Date Period	Saturday, Jan. 1 to Jan. 7	Saturday, Feb. 19 to Feb. 26	Monday, Mar. 21 to Mar. 28	Monday, May 16 to May 23	Monday, June 6 to June 13	Saturday, June 25 to July 2
8:30- 9:30 A. M.	49.0	52.5	80.5	62.5	67.5	43.5
9:30-10:30	58.5	59.5	83.0	70.5	72.5	50.0
10:30-11:30	58.5	60.0	84.0	70.0	73.5	50.0
11:30-12:30	59.0	58.5	84.0	68.0	74.0	50.0
12:30- 1:30 P. M.	57.0	58.0	83.0	67.0	75.5	49.0
1:30- 2:30	56.0	55.5	83.5	64.0	70.5	44.5
2:30- 3:30	58.0	57.5	82.5	64.5	71.0	43.5
3:30- 4:30	56.5	56.0	81.5	64.5	70.0	49.0
4:30- 5:30	56.5	54.0	81.5	62.5	67.0	48.0
5:30- 6:30	55.0	53.0	81.5	60.0	64.0	45.0
6:30- 7:30	54.5	53.0	81.0	62.0	63.0	43.0
7:30- 8:30	53.0	51.0	77.5	58.0	59.5	43.0
8:30- 9:30	53.0	47.5	76.5	56.5	57.0	37.5
9:30-10:30	51.5	46.5	75.5	53.0	53.5	37.5
10:30-11:30	46.0	44.0	74.5	46.0	51.6	34 0
11:30-12:30 A.M.	44.0	43.0	73.5	45.0	51.0	33.0
12:30- 1:30	42.5	41.0	73.5	36.0	49.5	30.5
1:30- 2:30	36.0	37.0	71.5	33.0	46.5	27.5
2:30- 3:30	32.5	33.0	70.0	33.0	43.5	25.0
3:30- 4:30	30.0	29.0	70.0	29.0	42.5	23.5
4:30- 5:30	29.5	28.5	69.5	33.0	40.5	22.0
5:30- 6:30	29.0	28.5	74.5	37.5	40.0	21.0
6:30- 7:30	31.0	31.0	74.5	36.5	42.0	26.5
7:30- 8:30	32.0	39.0	78.0	41.0	51.0	33.5
8:30- 9:30	...	...	...	...	...	...
Mean.	1,130,000	1,120,000	1,860,000	1,250,000	1,400.000	910,000
Max.	1,415,000	1,440,000	2,020,000	1,680,000	1,810,000	1,200,000
Min.	710,000	660,000	1,680,000	696,000	960,000	505,000

TABLE VII—Continued.

Day Date Period	Wednesday, July 20 to July 27	Tuesday, Aug. 3 to Aug. 10	Tuesday, Aug. 16 to Aug. 23	Friday, Sept. 2 to Sept. 9	Saturday, Nov. 17 to Nov. 23	Wednesday Dec. 7 to Dec. 14
8:30- 9:30 A.M.	36.5	37.0	35.0	62.5	88.0	73.0
9:30-10:30	44.0	40.0	45.5	62.5	91.5	79.0
10:30-11:30	46.0	49.0	49.0	62.5	91.0	82.5
11:30-12:30	45.0	46.5	46.0	60.0	90.5	82.0
12:30- 1:30 P.M.	44.5	43.5	43.0	57.5	89.0	81.0
1:30- 2:30	42.0	43.0	40.0	57.0	87.5	82.0
2:30- 3:30	44.0	42.0	39.0	56.0	87.0	82.5
3:30- 4:30	45.0	42.0	38.5	54.5	86.0	81.5
4:30- 5:30	44.0	41.5	38.0	53.0	85.5	79.0
5:30- 6:30	41.0	41.0	37.5	51.0	85.0	79.5
6:30- 7:30	39.5	39.0	34.5	49.0	83.5	80.0
7:30- 8:30	36.0	38.0	31.0	48.0	82.0	80.0
8:30- 9:30	34.0	36.0	29.5	46 5	82.0	79.5
9:30-10:30	33.5	34.0	28.0	45.5	82.5	78.0
10:30-11:30	30.0	31.0	26.0	42.0	82.5	76.5
11:30-12:30 A.M.	27.5	28.5	24.5	40.5	82.5	76.0
12:30- 1:30	...	...	...	...	...	...
1:30- 2:30	24.0	27.0	22.0	38.5	81.0	75.0
2:30- 3:30	23.5	24.0	20.0	37.5	80.5	71.0
3:30- 4:30	21.5	21.5	19.5	36.5	80.0	68.5
4:30- 5:30	20.5	20 0	19.0	38.5	79.0	65.5
5:30- 6:30	19.5	19.0	20.5	44.5	79.0	63.0
6:30- 7:30	18 5	21.5	24.5	46.0	79.0	58.0
7:30- 8:30	18.0	24.0	26.0	48.0	82.0	53.5
8:30- 9:30	24.5	22.0	28.0	56.0	84.5	60.5
Mean	803.000	816.000	765.000	1,193,000	2,021,000	1,790.000
Max.	1.105.000	1,175.000	1,175.000	1,500,000	2,200,000	1,980,000
Min.	430,000	445.000	445,000	880,000	1,890,000	1,285,000

TABLE VIII.

HOURLY RATE OF FLOW IN THE CHAMPAIGN SEWER FOR SELECTED DAYS.

Rate given in G.p.hr.

Period of	Jan. 16-17 Winter Flow	Jan. 31 Wet Weather	Feb. 20-21 Wet—but no rain	Mar. 6 No rain 3 days previous	Mar. 29 Rain 5 days previous	May 20-21 Commencing to dry	May 26-27 Maximum rain for year	Jund 7-8 Effect of May rain	June 29-3(Commencing to get dry weather
9 A.M.	31.5	63.5	34.0	35.4	72.5	66.5	103.5	72.5	43.5
10	36.0	60.5	40.5	48.5	71.0	69.5	103.5	79.5	48.5
11	43.5	60.5	56.0	51.5	78.0	63.5	110.0	76.0	46.0
12 P.M.	40.5	60.5	53.0	51.5	80.0	63.5	110.0	74.5	46.0
1	46.0	59.0	54.5	51.5	80.0	63.5	103.5	74.5	50.0
2	45.0	54.5	50.0	54.5	80.0	60.5	103.5	69.5	40.5
3	43.5	60.5	47.5	54.5	78.0	63.5	103.0	69.5	40.5
4	43.5	57.5	46.0	51.5	78.0	63.5	107.0	71.0	43.5
5	43.5	57.5	43.5	51.5	78.0	65.0	103.5	71.0	43.5
6	43.5	56.0	40.5	51.5	78.0	65.0	106.5	69.5	43.5
7	38.0	56.0	40.5	51.5	78.0	65.0	106.5	66.5	42.0
8	38.0	51.5	40.5	47.5	76.0	66.5	106.5	62.0	35.5
9	38.0	51.5	40.5	47.5	76.0	68.0	106.5	60.5	33.0
10	38.0	47.5	40.5	46.0	76.0	65.0	106.5	56.0	42.0
11	38.0	46.0	39.0	44.5	76.0	43.5	97.5	56.0	30.5
12 A.M.	31.5	46.0	38.0	43.5	74.5	42.0	97.5	54.5	28.0
1	29.0	42.0	38.0	42.0	74.5	40.5	95.5	53.0	25.5
2	28.5	39.0	33.0	38.0	73.0	35.5	95.5	51.5	20.5
3	21.0	35.5	30.5	33.0	73.0	32.0	97.5	48.5	20.5
4	18.0	35.5	28.0	30.5	73.0	28.0	97.5	47.5	22.0
5	18.0	35.5	25.5	28.0	73.0	27.0	97.5	47.5	22.0
6	18.0	34.0	25.5	28.0	76.0	27.0	103.5	46.0	21.0
7	20.0	33.0	30.5	30.0	74.5	28.0	97.5	46.0	24.0
8	28.5	38.0	38.0	36.5	76.0	34.0	97.5	60.5	25.5
	820.5	1,181.0	953.5	1,048.4	1,823.0	1,246.0	2,457.0	1,483.5	837.5
Corrected									
Mean	910.0	1,268.0	1,038.0	1,135.0	1,907.0	1,330.0	2.544.0	1,580.0	925.0
Max.	1,191.0	1,537.0	1.432.0	1,455.0	2,000.	1,750.0	2,700.0	1,910.	1,300.0
Min.	516.0	867.0	697.	763	1.900	725.	2,350.0	1,110	570.

CHAPTER IV.

OPERATION OF ACTIVATED SLUDGE PLANT.

By A. A. Brensky and S. L. Neave.

Operation Periods. Operation of the activated sludge plant covered a total number of three hundred and fifty-five days, which may be divided into three periods, the first extending from December 15, 1920, to April 6, 1921; the second from May 4, 1921, to October 31, 1921, and the third from November 16, 1921, to January 7, 1922. Previous to December 15, 1920, tank No. 1 had been in operation for about three weeks for a trial run.

Notes on Operation. The mechanical operation of the activated sludge tanks and machinery was on the whole satisfactory. Most of the repairs and changes were made during operation. The only shutdown for repairs was made on April 6, 1921, due to the wearing of the armature ring of the motor which operated the blower. Operation would have commenced again in a few days but during the month of April infiltration of ground water into the city sewers produced a weak sewage, and it was decided to postpone operation until the period of wet weather had passed. From July 11 to 14, 1921, each tank was examined while the other was in operation. The mechanism in tank No. 1 was found to have been striking the tray at one place and was repaired. The mechanism in tank No. 2 was in fair shape. Only a few leaks in the filtros system of the tanks needed repairing. The plant was closed down from October 31 to November 16 for the purpose of examining and cleaning the tanks preparatory to iron dosing.

During the time the first tank was in operation, previous to December 15, 1921, some changes were made in the second tank. First, it was found necessary to place concrete over the tray to fill in the irregularities of the surface. In some places, the rakes would scarcely pass the tray, while in other places the clearance was as great as six inches. The concrete shell greatly improved this defect. This difficulty was due to the quality of the material chosen for the construction of the trays. Since sludge collected and became septic in the peripheral downcast wells, it was thought that the peripheral wells were too large for the quantity of returning sludge. They were

made smaller in cross-section in the second tank by nailing two inch by four inch planks longitudinally to the staves.

Another difficulty in the operation of the second tank was due to air bubbles escaping from the aeration chamber to the settling chambers. These bubbles found their way up between the wooden shelf upon which the tray was nailed and the staves of the tank, and caused local disturbances in the sedimentation chamber. Asphalt was poured several inches thick between the concrete and wood staves which greatly improved conditions. Air bubbles, nevertheless, found their way through the asphalt joint at various places throughout the operation. The disturbances were minimized by trapping the air below the surface and localizing it to small areas. An outburst of escaping bubbles was noted in the daily data sheets as an ''air leak.'' Such an occurrence effected the turbidity of the effluent.

The laying of the filtros tile in the second tank was found defective. Air was observed to escape through cracks in the concrete at various places some distance from the plates. Apparently this air must have made its way from the air channels between the concrete and the wood floor to the cracks. (See Fig. 11.) This condition was corrected by placing new concrete reinforced with nails partly driven into the wood around both sides of the system of filtros plates. This repair was apparently successful, for but very few leaks were found when the places were examined.

A number of minor changes in construction were made early in the operation of the plant. On January 3, 1921, a wind break consisting of a canvas collar two feet in height was placed around the top of each tank to prevent eddy currents and ripples of the surface liquid.

Go-devils which were attached to the ends of each set of upper rakes were removed. Unfortunately one of the go-devils became wedged in the top of a peripheral well and did not allow enough clearance for the rake. It resulted in twisting one arm of the thickener, but did not impair its effectiveness.

The tanks were always cleaned before starting a new run. The two-inch outlets in the sand hutches were too small for rapid discharge, and much trouble was encountered during the cleaning of a tank. The blower required attention from time to time but did not necessitate a complete shut-down. Two men could overhaul, clean, and put the blower in running order in less than three hours.

Operating Records. The daily operation of the activated sludge plant was divided into three shifts of eight hours each, with an attendant for each shift. The routine measurements were re-

corded on daily data sheets by the attendants. Fig. 18 shows the blank forms that were used during the latter part of the second period of operation. These sheets were modified from time to time in order to take care of additional data or changes. Each reading was taken on the hour and is an average of the previous and following half-hours. The day was arbitrarily taken from 8:30 a.m. of one day to 8:30 a.m. of the following day. This arrangement made it possible to transport all the samples of a day's operation to the laboratory in one trip. Some of the readings on Sheet B were taken every two hours and others as often as was deemed necessary. The remarks on the general operation and observation were also recorded on this sheet. Sheet C of Fig. 18 is a form of the computation sheet made from the original data collected at the plant. Summaries of the daily mechanical results were prepared to cover the periods corresponding to the various experimental runs.

Sampling Points. The general plan in sampling was to collect representative portions of the raw sewage, the screened sewage, which constituted the influent to tank No. 1, the liquor flowing from tank No. 1 to tank No. 2, "overflow," the final effluent, and the sludge, at sufficiently frequent intervals to furnish average samples when composited for analysis. Samples were generally collected by the attendants in charge. Schedules of the samples and methods of collection were posted from time to time. A summary of the schedule of sampling and chemical determinations are given under the discussion of chemical data. Samples for microscopic examination were taken from May 4 to 18 and from September 21 to December 28. From June 6 to August 18 a daily sample of the screenings from the Dorrco screen was sent to the laboratory for moisture determination.

Various other samples were taken and many special tests were conducted which are not enumerated above.

Tests on the settleable solids in the aeration chamber and on the peripheral downcast wells of both tanks were made from May 3 to December 30, 1921. Four samples were taken daily at 7 a.m., 1 p.m., 6 p.m. and 12 a.m. The settleable solids were expressed as the per cent of the volume of sludge in a liter cylinder (70 c.c. to the inch) after settling for one hour. These tests were performed at the plant by the operators.

Collection of Samples. As a rule it is difficult to secure representative samples of unscreened and raw sewage. Samples of the unscreened sewage were collected at the inlet to the Dorrco screen by quickly submerging a wide-mouthed bottle of about 500 c.c.

Fig. 18

~STATE WATER SURVEY DIVISION~

~SEWAGE EXPERIMENT STATION~

TESTS SHOWING PERCENT OF SETTLEABLE SOLIDS AFTER ONE HOUR'S SETTLING IN A LITER CYLINDER

SHEET E

DATE	UPCAST 1				TRAY 1				UPCAST 2				TRAY 2				SLUDGE		
	TIME of SAMPLING				TIME of SAMPLING				TIME of SAMPLING				TIME of SAMPLING				TIME	QUAN GALS	
	A.M		P.M.		A.M.	A.M.	P.M.	P.M.	A.M		P.M.		A.M		P.M.				
	12-1	7-8	1-2	6-7	12-1	7-8	1-2	6-7	12-1	7-8	1-2	6-7	12-1	7-8	1-2	6-7			

~STATE WATER SURVEY DIVISION~

~SEWAGE EXPERIMENT STATION~

SHEET C

PERIOD	INFLUENT EFFLUENT GALLONS	SLUDGE DRAWN TIME	SLUDGE DRAWN GALLONS	CHAMPAIGN SEWAGE 1000-GAL.
INFLUENT		TOTAL		
SLUDGE		CORRECTED		
EFFLUENT		MAX. RATE		
		MIN. RATE		

MEASUREMENT OF AIR USED		
PRESSURE #/□" AT BLOWER & TKS.		
TEMP. °C AT BLOWER & BETWEEN TKS		

TOTAL AIR USED			
PLACE OF MEASUREMENT	ORIFICE 1¼	VENTURI	TANK #1
AV. READING FOR DAY			
FLOW IN CU. FT MIN.			
FLOW FOR ____ HRS.			
CORRECTION			
AIR AT 60° F & 6#/□"			
AV. OF ORIFICE & VENTURI =			

	TANK #1	TANK #2
PERCENT OF AIR TO EACH TANK		
FLOW INTO SETTLING CHAMBER		
RATIO OF FLOW TO INFLUENT		
SLUDGE OVERFLOWING (TIME)		

DORRCO SCREEN FLOW

AV. HRLY. FLOW GAL FLOW FOR HRS. -

WET SCREENINGS COLLECTED LBS.

NOTE —

POWER CONSUMPTION FOR HRS. KW. HRS.

PLANT OPERATED (BLOWER) HOURS

REMARKS —

~STATE WATER SURVEY DIVISION~

~SEWAGE EXPERIMENT STATION~

SHEET A

DATE

TIME OF READING	TOTAL AIR MEASURE: INCHES OF MERCURY LEFT	INCHES OF MERCURY RIGHT	TEMP. °C	VENTURI METER	ORIFICE 1¼"	AIR TO TANK #1: INCHES OF MERCURY		TEMP. °C	INCHES OF WATER	SCREEN'D SEWAGE INCHES ON WEIR	EFFLUENT INCHES ON WEIR	SLUDGE DRAWN TIME	SLUDGE DRAWN AM'T IN GAL.	CHAMP'N SEWAGE INCHES ON WEIR	TIME OF SAMPLE	RECORDER

~STATE WATER SURVEY DIVISION~

~SEWAGE EXPERIMENT STATION~

SHEET B

DATE

TIME OF READING	WASTE AIR INCHES H_2O	FLOW IN SETTLING CHAMBER: WEIRS	HEAD IN INCHES ON WEIRS TANK No. 1: 1.	2.	3.	TANK No. 2: 1.	2.	3.	RECORDER
AVE.									

TIME OF DAY SLUDGE OVERFLOWING TKS.	TANK No. 1		TANK No. 2	
STARTING				
STOPPED				

REMARKS ON OPERATION

TIME	

WEIGHT OF WET SCREENINGS						POWER READING		
FROM	TO	TOTAL	BOX	NET	TIME	TIME	METER	KHRS

TEMPERATURES IN CENTIGRADE

TIME	9A	11A	1P	3P	5P	7P	11P	6A
SEWAGE								
EFFLUENT								

capacity. Samples of the screened sewage were obtained as it passed the 12-inch weir. The stirring and mixing in the screen assisted greatly in securing a representative sample of the screened sewage. The effluent from tank No. 2 was collected as it flowed into the effluent weir box. During the winter of 1920 and 1921 a small portion of the effluent was by-passed through the pump building for sampling. The overflow sample from tank No. 1 was collected as it entered the six-inch overflow pipe leading to tank No. 2. Samples of the aeration chamber sludge were collected at the upcast wells, and were called sludge from upcast well No. 1 or No. 2. Tray samples collected at the sludge removal pipes were designated as Tray 1 or Tray 2 samples.

Physical Characteristics of Sludge. The process of activated sludge purification is primarily a problem in clarification of sewage by aeration, which involves the study of the physical characteristics of the sludge, and particularly, the rate of subsidence. The degree of clarification of the supernatant liquid and the density of the settled sludge, other conditions being equal, are directly dependent upon the rate of subsidence and the nature of the sludge. Furthermore, in a Dorr-Peck tank the study becomes more important and more complicated because the mechanical features are so closely related. One condition cannot be changed without a variation of several conditions.

The nature and the color of the activated sludge changed with the seasons and with the conditions of operation. During winter and spring a dark gray sludge predominated; the flocs were large and distinct. During summer and fall, the unsettled sludge was of a light gray color, much thinner and lighter in texture. With few exceptions the flocs were not as well formed as those of the winter and spring. During the last period of operation, when iron sulphate was added to the sewage, a very characteristic reddish-brown sludge was obtained. The coarser and finer flocs seemed to settle evenly. A line of demarcation between sludge and supernatant liquid was evident the first minutes of subsidence. Some very light flocs, however, remained in suspension for many hours, and were discharged with the effluent which greatly effected its stability.

Rate of Subsidence. The settling rate of activated sludge samples was determined in liter cylinders (70 c.c. equivalent to one inch height). Fig. 19 shows theoretical rates of subsidence curves of sludge collected in the aeration chamber and on the tray. It gives the figures for relative volumes of solids settling in a liter cylinder of sludge during the first hour. For example, after the first ten minutes of settling the line of demarcation between the settleable

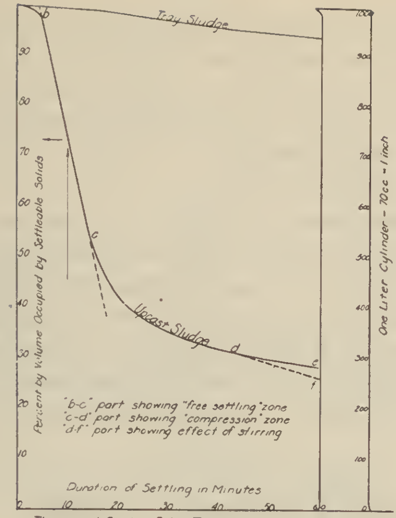


Fig. 19

solids and the liquids was at 730—in other words, the sludge occupied 73 per cent of the original volume.

The settling curves of the sludge as drawn from the aerating chamber are divided into two distinct parts. The first part, b-c, is a straight line and is known as the period of free settling, that is, each particle or floc falls unhindered by the presence of others. The rate of subsidence is constant during this period. The steeper this line the greater becomes the rate of free settling. The second part of the curve is known as the compression zone of the sludge settling curve. It commences just where the flocs and particles of sludge interfere with each other and continue to settle collectively at an increasingly retarded rate. During this period the flocs are partly supported by each other, and some of the accompanying moisture is expelled by the pressure of the particles exerted upon each other. From the point "d" the rate is practically nil and little decrease in volume will occur with continued detention. The dotted line d-f shows how gentle stirring with a glass rod affects the sludge volume. The settling action in a liter cylinder is in a way characteristic of that occurring in the settling chambers. The effect of the Dorr thickeners is likewise similar to that produced by stirring with a glass rod.

The curve of subsidence of the tray sludge in Fig. 18 shows no free settling rate and very little decrease in volume. It has been thickened sufficiently on the tray so that further settling will not decrease the volume materially. Under these conditions the sludge is at the best stage to be returned to the aeration chamber, or to be discharged from the tank.

There occurred, however, many variations from these ideal subsidence rates. Several factors, such as the state of activation, character of the sewage, temperature, and dilution, all independent of the Dorr-Peek tanks as well as the mechanical features of design influenced the nature and character of the sludge. The effects of some of these factors are discussed below.

Effect of Reaeration.[33, 34] Much trouble was experienced in securing a sludge with a good consistent settling rate, especially during the summer months. On August 8 and September 13 some experiments upon samples taken from the aeration chamber were made on a small scale in order to study the effect of aeration only. Twelve gallon samples of each were aerated separately in vitrified tiles equipped with filtros plates. Fig. 20 shows the effect of continued

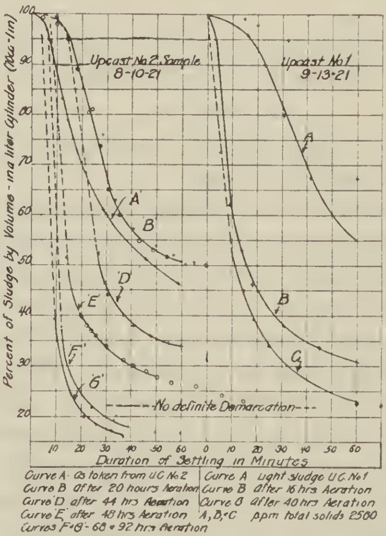
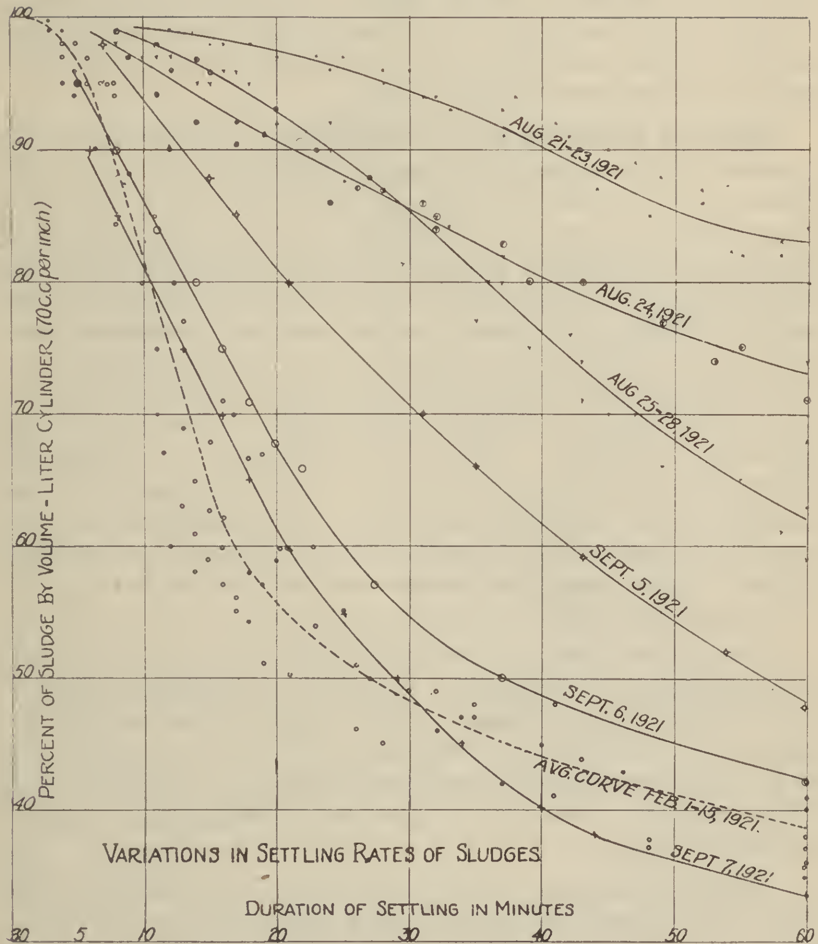


Fig. 20

aeration upon the rate of subsidence. The condition of operation previous to the time of sampling, and the effect of aeration are tabulated below.

	Aug. 9, 1921	Sept. 13
Test plant flow for previous days (5), gallons	70,000	67,000
Air used per gallon	0.84	1.47
Total Champaign sewage flow (1000 gal.)	780	934
Average nitrates in influent (p. p. m.)	0.4	0.7
Ratio test plant to total flow	9.0%	7.2 %
Maximum free settling rate, feet per hour	1.36	1.2
Theoretical capacity of settling chamber, gal. per hr.	2,200	1,920
Effect of aeration only (time), hours	44	16
Free settling rate, feet per hour	3.0	3.6
Capacity of settling chamber, gallons per hour	4,800	5,800
Con'd aeration, hours	48	40
Settling rate, feet per hour	4.3	3.9
Capacity, gallons per hour	6,900	6,200.

Fig. 21


AUG 21-23, 1921
AUG. 24, 1921
AUG 25-28, 1921
SEPT. 5, 1921
SEPT. 6, 1921
AVG. CURVE FEB. 1-15, 1921.
SEPT 7, 1921
PERCENT OF SLUDGE BY VOLUME - LITER CYLINDER (70c.c. per inch)
100
90
80
70
60
50
40
VARIATIONS IN SETTLING RATES OF SLUDGES
DURATION OF SETTLING IN MINUTES
0
5
10
20
30
40
50
60

Comparing the results it is seen that in the case of the first sample a marked change in the settling property of the sludge required forty-four hours aeration while the second sample required but sixteen hours. This is partly due to the condition of the sludge at the time of sampling. The first sample was taken at a time when the sewage was weaker and when less air per gallon was used than at the period of taking the second sample. After forty-eight hours of aeration, the free settling rates approached each other and increased very little. The volume of the settleable solids, however, continued to decrease after forty-eight hours aeration.

Effect of Sewage on Rate of Subsidence. Another factor, the character of the sewage, had a marked effect upon the rate of subsidence. Fig. 21 shows an average settling curve for samples of sludge taken from the aeration chamber of the second tank during February 1 to 15, 1921, a comparatively wet period, and also several curves for samples taken from the same tank from August 20 to September 7, 1921, a dry period in which there were occasional heavy showers. The storm water entering the sewer, increased the free settling rate of the sludge by producing a weaker sewage and by diluting the sludge itself. Dilution of the sludge content in the tanks assisted good operation. The diurnal variation in the settling rate noted below is probably due to dilution. In the mornings the sludge blanket, i. e., the division between the settleable solids and the clear liquid, was comparatively lower than in the afternoon. In the early morning a dilute sewage was pumped into the tanks while the period of the strongest sewage was from 9 a.m. to 12 p.m.

Temperature changes in the tank during the day were slight, not varying over 2° centigrade. A maximum temperature of 26° C in the summer and a minimum of 10° C in the coldest weather was experienced. The effect of other factors on the sludge was much greater than the effect of temperature variations. A sudden change in the barometric pressure not infrequently affected the height of the sludge blanket.

Diurnal Variations. Fig. 22 represents the diurnal variations of the volume of settleable solids in the aeration and settling chamber of both tanks. These curves are averages of the settleable solids determined in a liter cylinder after one hour's settling. They were taken four times per day from May 4 to August 1, 1921. From this figure it is seen that the maximum volume on the trays occurs in the morning about 7 a.m.

DAILY VARIATION IN SETTLEABLE SOLIDS
OF UPCAST WELL & TRAY SLUDGE SAMPLES

Time of Day	U.C. No. 1	Tray No. 1	U.C. No. 2	Tray No. 2
12 to 1 A.M.	42 %	47 %	51 %	64 %
7 to 8 A.M.	41	54	52	69
1 to 2 P.M.	35	42	44	58
6 to 7 P.M.	39	43	47	59

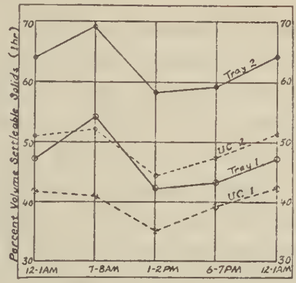


Fig. 22

The daily variations were independent of the removal of sludge from the system. This can be seen in Fig. 23. The volume of sludge drawn is represented by the areas of the blocks on the lower line.

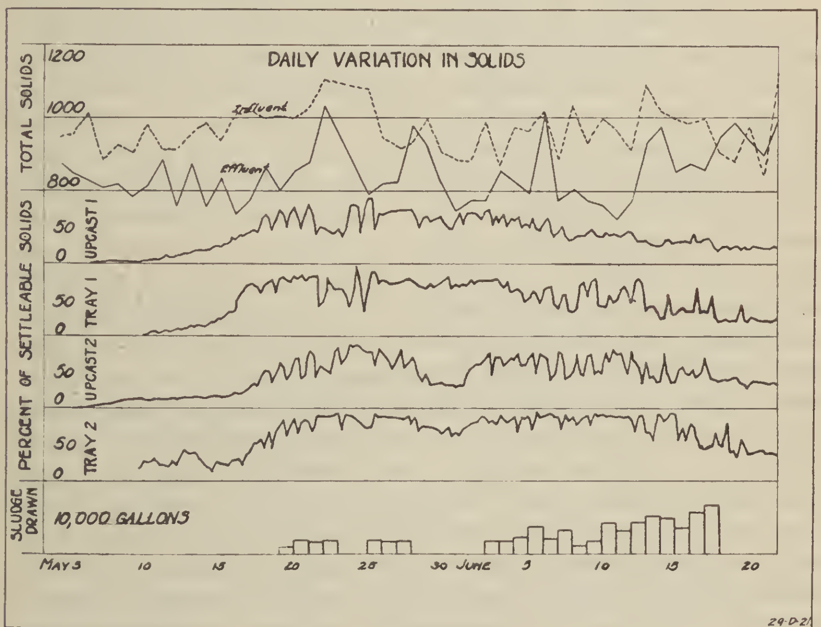


Fig. 23

This figure shows many deviations from the ideal represented by the averaged figures in the diurnal variations. The large number of variations may to some extent be attributed to the variations of the

sewage from day to day, and others to the mechanical features of the Dorr-Peck tank. These curves are of general interest since they show the variations from day to day and week to week in the volume of settleable solids.

Weight and Volume of Settleable Solids. On account of the wide variation in sludge by volume it was thought advisable to direct attention to the control of the density of the sludge. For this purpose the total solids were determined. Sometimes the sludge was exceedingly light and feathery in appearance and did not purify as effectively as denser sludge. Fig. 5 shows an attempt to determine some relation between the total solids and the volume occupied after one hour's settling. These points show that many more factors effect this relation. With as wide and irregular variations as these it is apparent that in our case at least it was impossible to judge the effective amount of sludge by sedimentation. If the variations were only slight it might still be possible to operate using settleable solids as a control.

Two conditions of operation in the mechanical design of the tanks which affected the rate of subsidence were the overflowing of sludge from the first tank, and the ratio of the sewage flow to the inflow into the settling chamber. In normal operation the sludge was allowed to overflow from the first tank into the second. Overflowing sludge was caused by overloading the capacity of the settling chamber. This may also occur when the sludge is not in proper condition and fails to thicken properly. The effect frequently extended to the second tank, and sometimes caused particles of light sludge to overflow with the effluent. Overflowing sludge was employed as a guide in drawing excess sludge, although as is shown above this was not a satisfactory means of judging the amount of sludge. It is possible even with uniform conditions of the sewage, temperature and activation, to have a large daily variation in the settleable solids in the aeration chamber and on the tray. The factor effecting this was the inflow to the settling chamber. For example, if twice the normal flow passed into the settling chamber for one hour an equal increase would go through the peripheral wells carrying the densest sludge back into the aeration chamber. Probably the feature hardest of control was the relative capacity of the volume of settling to that of the area. Sometimes it was impossible to thicken the sludge properly although allowed to accumulate to a rather large volume. Under these conditions sludge would overflow with the effluent.

It has been shown that dilution assisted the rate of settling.

Attempts were made to control the total solids to a given weight, but it was found that it limited the total solids of the tray sludge.

In summarizing the importance of sludge settling it may be said that the Dorr-Peck tank limited the variation of control to a much smaller range than the physical characteristics of the sludge allowed.

Grit Chamber. The amount of grit retained by the grit chamber was little—in fact, no experiments were conducted, due to the low amount of grit in the sewage. For this reason this step in the process could have been omitted. The bar screen was removed as only paper pulp was collected by it. A heavy scum collected over the surface of the chamber. The velocity through the channel varied from .8 to 1.2 feet per second. In former experiments here, similar results were found with a grit chamber one foot wide and thirty-four feet long.

Materials which would ordinarily roll along the invert of the sewer passed by the grit chamber. Most of the grit that would collect was mineral matter with varying amounts of organic matter. At times grit of the appearance of coffee grounds was collected. The grit chamber was cleaned out three or four times during the year, which was done by increasing the sewage flow through the grit chamber, by passing the screen, and returning the flow to the main sewer. By means of a shovel or stiff brush the contents in the grit chamber were stirred up and washed out. The scum which collected upon the surface became putrescent during the summer weather and was covered to prevent fly breeding. During the rainy seasons greater amounts of dirt and sand were present in the sewage than in an ordinary flow.

Dorrco Screen Results. The Dorrco screen was primarily operated to provide screened sewage for the activated sludge experiments. Extensive tests were being conducted at the time by the Connecticut State Board of Health on an improved type of the Dorrco screen and so no attempt was made to carry on similar experiments. Some work, however, was done with the screen, and is given below.

The screen is described in Chapter II, page 34. The volume of sewage entering the screen chamber was regulated by a gate placed in the inlet channel; and the rate of flow was measured after passing the screen drum. The solids were collected on the screening surface and discharged into the pit. The operator with the aid of a perforated dipper collected the screenings regularly during the day from the pit and placed them in perforated cans. The screenings were weighed daily after twenty-four hours of draining and samples were sent to the laboratory for moisture content determinations. The

screen drum was used at Mt. Vernon, N. Y., by the Dorr Company. It was originally designed for a life of six months, but with more or less repairs it continued to operate during the activated sludge experiments.

Three different screen mediums were used, namely, one-half inch by one-sixteenth of an inch slots parallel with the axis of rotation, one-half inch by one-sixteenth of an inch slots parallel to the direction of rotation, and one-sixteenth of an inch circular perforations. The net screen width was six inches, and with the slot screens, 26 to 28 per cent of the total effective screen area were openings. The screen was submerged from 44 to 48 per cent of its diameter, depending upon the rate of flow through the screen.

The rotation produced a head from two to three inches inside the screen and established a flow outwardly through the screen. This kept the solids washing into the pump pit. The best speed of rotation was from twenty-two to twenty-six revolutions per minute, or an average peripheral velocity of 300 feet per minute. The fin assisted in dislodging the solids from the screen surface.

During the winter a lime soap froze to the screening surface, and it was necessary to clean the screen as well as to keep it entirely covered. Cleaning was done by a jet of steam playing against the drum. In the summer some material would occasionally remain collected in the slots and partly blind the openings. With the use of a wire brush and kerosene the screen was cleaned in a few minutes as it revolved.

Table IX gives a summary of the removal of solids by weight. The latter tests extended from June 7 to October 29.

Better results could have been obtained if changes in design could be made, but the location limited modifications. The size of the screen pit (one and one-half square feet area) was far too small for the rest of the screen and many solids would find their way through the screen. In the latter part of August the area of the screen pit was increased to about four square feet and a circulating flow from the screen pit to the inlet of the screen was allowed; the level in the screen pit was about two inches higher than the sewage level in the inlet to the screen. This was due to the rotation of the screen.

Some measurements on the loss of head through the drum were made. These can be summarized by saying that with the rate of flow of 200,000 gallons per day, three inch difference between the inlet and outlet sewage level was measured; and with the rate of flow of 50,000 gallons per day the loss of head was from one to one and a half inches. These experiments were made with the screen medium having slots parallel to the direction of rotation.

TABLE IX.

DORRCO SCREEN OPERATION.

Period From—to	No. of Days	Scr'ngs as Weighed Lbs.	Moist of Scr'ngs	Wt. of Dry Scr'ngs	Flow Thru Screen 1,000 Gal.	Total Champ. Flow M.G.D.	Ratio Sc. flow to Total	Removal p.p.m.	Remarks
Jund 7-30	24	....	85.2	5.4	159	1.10	14.5	4.1	Screen worn out.
July 18-28	11	76.5	82.0	14.0	164	.89	18.5	10.0	New screen—
July 29-Aug. 8	11	62.0	84.0	10.4	135	.84	16.0	9.3	slots parallel.
Aug. 18-23	6	77.0	84.8	11.7					To direction
					120	.76	15.7	11.7	of rotation.
Sept. 13-23	11	76.0	84.0	12.3	123	1.05	11.7	12.0	
Oct. 3-15	12	79.0	85.0	11.9	137	1.14	12.0	10.4	
Oct. 15-29	15	91.0	85.0	13.7	135	1.20	11.2	12.2	
Weighted Average	66	79.0	....	12.5	136.0	1.01	13.0	10.0	

CHAPTER V.

BIO-CHEMISTRY OF THE PROCESS.

By A. M. Buswell and S. L. Neave.

Nitrogen Cycle. Before proceeding to the discussion of the experimental data bearing on the chemical reactions of the nitrogenous compounds we shall review briefly the current opinions on the subject.[35]

The conventional nitrogen cycle[36] (Fig. 24) used in most text

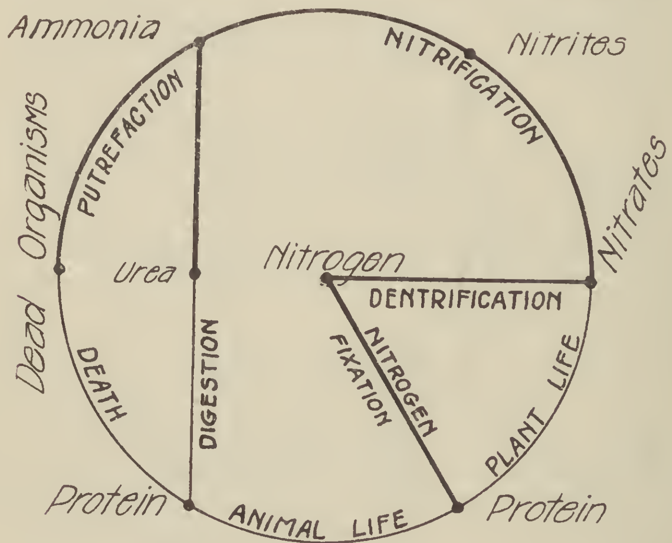


Fig. 24

books on sanitary subjects emphasizes certain distinctions which are not of particular importance when applied to the reactions in sewage disposal. For instance, the change from vegetable to animal protein does not materially affect the final decomposition reactions although it is represented by a large arc of the circle. The probable chemical course of some of the oxidation and reduction reactions is not brought out clearly by the diagram, nor is the reversibility of these reactions emphasized sufficiently for the purposes of the present discussions. Denitrification is represented as the direct reduction of ammonia to nitrogen, while undoubtedly nitrite is formed as an intermediate

product. Nitrate is also represented as being formed directly into plant protein while chemical evidence requires its preliminary reduction to ammonia. By including death in the circle the reactions are made to appear to take place in one direction only, i. e., clockwise, while as shown below all of the reactions are reversible and must be so regarded in interpreting the bio-chemistry of sewage disposal. We suggest, therefore, representing the chemical reactions of the nitrogen cycle as shown in Fig. 25.

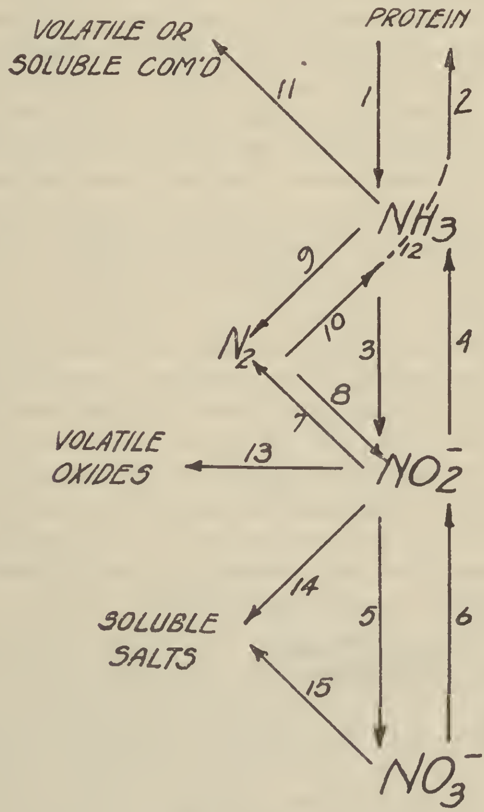


Fig. 25

Ammonification. If we begin with proteins at the top of the figure, we note first that these may be decomposed by means of hydrolysis to form ammonia. The intermediate steps have been worked out by Robinson.[37] Apparently amino acids are first formed

and these may then be further broken down to ammonia, organic acids and CO_2 according to one or more of the following reactions:

$$R{\cdot}CH{\cdot}NH_2{\cdot}COOH + H_2 = R{\cdot}CH_2COOH + NH_3$$ [38]
$$R{\cdot}CH{\cdot}NH_2{\cdot}COOH + O_2 = RCOOH + CO_2 + NH_3$$
$$R{\cdot}CH{\cdot}NH_2{\cdot}COOH + H_2O = RCH{\cdot}OH{\cdot}COOH + NH_3$$ [39]
$$R{\cdot}CH{\cdot}NH_2{\cdot}COOH + H_2O = RCH_2{\cdot}OH + CO_2 + NH_3$$

The reactions are undoubtedly the result of microbial activity. Marchal[40] attributed ammonification in the soil to the activity of the B Mycoides group and B fluorescens liq. while Conn[41] claims that the Mycoides organisms are relatively poor ammonifiers and that two organisms Ps. fluorescens and Ps. caudatus which multiply rapidly in freshly manured soils are the important ammonifiers. Waksman[42 43] has shown that fungi, especially actinomycetes, are good ammonifiers. Doryland's[44] investigation of these reactions from the standpoint of energy requirement of the bacteria indicate that ammonia formation is incidental. The bacteria attack compounds from which they can obtain energy; if suitable non nitrogenous compounds are present proteins will be attacked but slightly, or not at all, and consequently little or no ammonia will be formed.

Nitrification. The fact that NH_3 may be oxidized to nitrite and then to nitrate by Nitrosomonas and Nitrobacter, respectively, is so thoroughly discussed in texts both on soil chemistry and on the chemistry of sewage disposal, that it requires but passing mention here. In the soil $CaCO_3$ or $MgCO_3$ and CO_2 seem to be essential to the reaction. Since these organisms are sensitive to changes in acidity it seems probable that the buffer effect of these carbonates may explain their beneficial action. No intermediate chemical products between NH_3 and nitrite have been detected so that this step of the reaction is not definitely known.

Loss of Gaseous Nitrogen. The data on this phase of the nitrogen cycle are in many cases of a negative character. Experimenters have failed to show a balance of nitrogen, and where the difference was greater than could be otherwise accounted for, it was attributed to evolution of gaseous nitrogen. Russel refers to the works of Chick[45], Adeney[46], and Muntze and Laine[47] for evidence of the occurrence of this specific reaction in sewage disposal. A review of the references, however, raises a question as to whether this reaction occurs to any such extent as is generally supposed. Chick, in her work on trickling filters (Table II, loc.cit.), does not take account of the nitrogen in the microbial growth on the filters. This is also true of the work of Frankland quoted by Adeney and Letts, loc.cit., and of that of Muntz and Laine. In the experiments

of Adeney and Letts septic tank effluent was incubated with the addition of KNO_3. The incubation took place in tightly stoppered bottles. At the conclusion of the experiment the various forms of nitrogen, with the exception of the Kjeldahl Nitrogen, were determined and the dissolved gases were analyzed; non-nitrated blanks were similarly treated and analyzed. In the experiments in which KNO^3 was added, the nitrate was assumed to be completely reduced and an excess of dissolved nitrogen over that in the blank was found. The excess was practically equivalent to the nitrates reduced. This experiment when finished gave six sets of results, three of which were discarded on account of errors due to the difficulties of the analytical procedure. On the basis of the three remaining experiments the authors apparently assume that when nitrate is reduced it is converted quantitatively into nitrogen, for in subsequent experiments by these authors nitrate reduction is referred to as "loss of nitrogen." This, as will be shown later, is contrary to our experience.

From purely chemical considerations there appear to be two ways in which the formation of nitrogen may be brought about. First, by the direct oxidation of ammonia, with the formation of N_2 and H_2O. This occurs when ammonia is burned in pure oxygen. A similar oxidation takes place when ammonia reacts with chlorine or bromine, in which case halogen acid and nitrogen are formed. Second, by the reduction of nitrates and nitrites by organic matter with the formation of nitrogen and Co_2. When nitrates are reduced in the course of inorganic reactions, considerable amounts of ammonia as well as various oxides of nitrogen are formed.

There is evidence in favor of both of these courses of reaction. In the sewage beds studied by Chick (loc.cit) and Muntz and Laine (loc.cit.) loss of nitrogen was said to have occurred under ample aeration, while in the experiments of Adeney and Letts, (loc.cit.) the reaction was undoubtedly one of reduction. When nitrites and ammonia are both present "auto-oxidation reduction" may occur, one nitrogen atom oxidizing the other and itself being reduced according to the well known reaction $NH_4\ NO_2 — N^{2+}2\ H_2O$.

K. Scheringa[48] claims that with a concentration of 4 mg. of NH_4^+ and 2 mg. NO_2^- per liter the last reaction did not take place. From the references cited we must conclude that there is no data in the literature showing that nitrogen gas is formed to any great extent during the reactions of sewage purification. The forms of nitrogen left undetermined by the earlier experimenters would probably have accounted for most of the "loss."

Nitrogen Fixation. By purely chemical reactions nitrogen may

be caused to combine in two well known ways. Oxidation may be brought about by means of electrical discharge, which reaction occurs to a slight extent in nature during thunder storms. Reduction or combination of N with hydrogen can be brought about under proper conditions with the aid of catalysts. One can hardly imagine that this reaction could occur in nature. These reactions have little more than theoretical importance in the present connection.

Nitrogen fixation is brought about in nature by means of the nitrogen fixing organisms, clostridium pasterianum, aztobacter, and the symbiotic forms, all of which with other less known members of the group will be found described in any text on general bacteriology.

The course of the reaction by which these organisms effect the fixation of nitrogen is entirely unknown. To avoid complicating the diagram (Fig. 25) it is represented by a broken arrow passing through ammonia to protein. Since in general the reactions go on under anaerobic conditions there is some reason for the path chosen. Experimental results point to the fact that carbon compounds such as sugars are among the substances which stimulate these organisms, while soil biologists seem unanimous in the opinion that large amounts of nitrogenous organic matter, such as are met with in sewage, would be unfavorable if not strictly inhibitory to these organisms.

Denitrification. This process, the reduction of nitrates and nitrites, while brought about by bacteria, is not specific. A variety of organisms can effect the reaction, the presence of nitrates and easily oxidizable organic matter being the only essentials. The products of the reaction include nitrogen, oxides of nitrogen, ammonia and protein. The production of the first three has been discussed above. The production of protein from nitrates as well as from ammonia has been noted by a large number of workers (Koch, A.,[49] Pettit, H., Doryland, C.,[50] and others).

It should be noted that the term denitrification in its strictest sense is used to indicate reduction of nitrates and nitrites with the loss of nitrogen. In a broader sense it may include the assimilation of nitrates referred to above. Assimilation of nitrates and ammonia to form insoluble bacterial protein is sometimes referred to as nitrogen fixation, since the leaching out of nitrogen is thus prevented.

In summarizing the nitrogen cycle shown in the diagram (Fig. 25) we note first that all the changes are brought about by reversible chemical reactions which in practically all cases are catalyzed by bacteria. The usual course of mineralization is indicated by the arrows pointing straight downward from "protein" and under cer-

tain conditions, or, when desired, the process may be interrupted at any one of the indicated steps. (For the sake of simplicity the intermediate steps in ammonification have been omitted.) The steps from ammonia to nitrate are peculiar in that they are brought about by specific organisms. At the nitrite stage the reverse action may be split into two paths, one of which gives nitrogen by reduction, and the other, ammonia and protein by assimilation. The downward reactions result in the formation of nitrogen or its compounds which may ultimately be lost, while the upward reactions tend toward the retention of nitrogen as protein. If we classify the reactions under the two main headings, loss of nitrogen, and formation of protein, they may be grouped as follows:

Loss of Nitrogen	As N_2	Reduction of NO_3 6 & 7 Oxidation of NH_3 9 Auto oxidation and reduction 9 & 7
	As Compounds	Soluble NH_4^+, 11; NO_2^-, 14; NO_3^-, 15. Volatile oxides 13
Formation of Protein	Fixation	Bacterial 12 Oxidation 8 Reduction 10
	Assimilation	NO_3, 6, 4, 2 NO_2, 4, 2 NH_3, 2

Nitrogen Cycle in Activated Sludge Tanks. Previous experiments carried on by the Dorr Company with the co-operation of Professor D. D. Jackson of Columbia University had indicated that the activated sludge process as carried out in this apparatus did not result in the loss of nitrogen. Accordingly, one of our first experiments was to determine whether or not nitrogen was lost in this process. Although the operation of the plant had not been sufficiently standardized to completely prevent appreciable quantities of sludge overflowing with the effluent, thereby making the stability results uncertain, it was decided to run a careful nitrogen control to determine whether or not nitrogen was lost in the process.

For this purpose hourly samples (for details of sampling and analytical procedure see page 116)of the effluent and influent were taken and composited for analysis. The sludge drawn from the apparatus was carefully measured and a sample taken for analysis. The analyses included determinations of free and albuminoid ammonia, nitrates, nitrites and total organic nitrogen by the Kjeldahl method. The ammonia, nitrate and nitrite, and organic nitrogen, all expressed

as nitrogen, were added together, converted into pounds per 1,000 gallons and multiplied by the flow for each day. These sums were tabulated for the entire period from December 14, 1920 to February 18, 1921, and are presented in a preceding table (Table III). From this table it will be observed that during a run extending over sixty-three days there was a net loss of .43 per cent of nitrogen. Since this amount is within the limits of experimental error we would conclude that our methods of sampling and analyzing have been sufficiently accurate to keep track of all of the nitrogen, and that in this process there is no volatilization of free ammonia and no reaction taking place whereby gaseous nitrogen is formed.

Some of the determinations necessary to keep track of the nitrogen balance had to be discontinued at the end of the above run in order to allow other tests to be made. They were resumed, however, on the third day of May and the tabulation of the results separated into ten to fifteen day periods, extending up to the end of the run, is shown in Table X.

The data is presented in this form in order to point out the danger of drawing conclusions from short periods of operation. For instance, it appears that from the 14th to the 21st of May, approximately 11 per cent of the entering nitrogen was lost, while from the 2nd to the 15th of June there was an apparent gain of 25.7 per cent.

Such a result as this last would lead one to infer that there must be considerable fixation of atmospheric nitrogen, while as a matter of fact, there was undoubtedly an accumulation of sludge from the preceding period which was drawn during the first two weeks of June. Averaging the results for the entire period we note the apparent gain of one and a half per cent of nitrogen. When the difficulties involved in obtaining an average sample are considered as well as the limits of accuracy of the analytical procedure, we regard this value of one and a half per cent as being within the limits of experimental error, and checking reasonably well with our loss of .4 of a per cent, the result of the previous run. It has been claimed that in the presence of iron and crenothrix like organisms there was marked fixation of atmospheric nitrogen. From November 17 to December 27, $FeSO_4$ was added to the screened sewage to the extent of 9.6 p.p.m. of Fe^{++} for the purpose of stimulating these organisms. Table X, however, indicates no fixation.

These results are interesting when compared with results of nitrogen recovery experiments on activated sludge made by other workers with different types of activated sludge tanks, and using much larger quantities of air. For instance, Pearse and Mohlman[32] (in

TABLE X.

NITROGEN BALANCE.

Duration of Run		Influent		Effluent		Sludge		
Date	Days	Average Gals/24 hrs.	Total lbs. N_3 in Inf.	Gals/24 hrs.	Total lbs. N_3 in Eff.	Total gals. drawn during run	Total lbs. N_2 in sludge	Loss or Gain of Nitrogen (Per cent)
May 3-13	11	88,200*	200.3	84,100	184.3	none	......	— 7.9
" 14-21	8	86,700	163.9	85,600	122.2	9,050	23.68	—10.9
" 22- 1	11	88,500	152.0	86,600	118.7	17,100	43.07	+ 6.4
June 2-15	14	91,400	273.0	85,200	176.1	87,150	166.85	+25.7
" 16-30	15	87,700	338.9	85,800	277.3	26,840	25.04	—10.8
July 1-10	10	84,800	216.1	81,100	210.2	3,700	3.08	— 1.3
" 15-31	17	78,600	343.9	73,500	268.4	88,100	100.40	+ 7.2
Aug. 1-15	15	70,500	293.2	62,800	187.4	92,450	101.50	— 0.1
" 16-21	6	62,000	132.6	57,000	65.9	30,100	83.60	+12.7
" 22- 1	11	64,600	207.6	62,800	143.3	19,630	51.40	— 6.2
Sept. 2-20	19	66,500	345.3	64,900	248.4	4,460	129.20	+ 9.3
" 20-28	8	66,600	147.0	59,500	102.8	8,070	63.60	+13.2
" 29- 6	8	63,800	151.7	54,600	134.2	9,200	101.47	+55.3
Oct. 7-16	10	102,300	320.6	99,200	264.3	5,300	67.30	+ 3.4
" 17-31	15	93,800	486.2	89,100	374.1	4,900	117.20	+ 1.0
Nov. 16-30	15	80,500	273.1	80,500	240.7	none	.....	—11.8
Dec. 1- 7	7	75,200	150.9	75,200	98.5	none	.....	—34.7
" 8-28	21	77,800	508.6	75,300	316.8	3,800	172.18	— 3.8
Total	221	1,429,500	4,704.9	1,362,800	3,533.6	409,850	1,252.57	......
Average		79,400		75,700	......	27,300	....	+ 1.8

* Includes filling the tanks.

their report to the Board of Trustees of the Sanitary District of Chicago on the industrial wastes from the stockyards and Packingtown, dated January, 1921, pages 29 and 150) state that in the summer there is a 41 per cent loss of nitrogen, and in the winter a 23 per cent loss of nitrogen. In the Packingtown experiments it might be noted that three and a half to eleven cubic feet per gallon of air was used. There is, of course, danger of being misled when comparing results obtained on different sewage.

Fowler[51], in an extensive review of the conservation of nitrogen with special reference to activated sludge, states that "there is little doubt that not only does the activated sludge process recover the nitrogen present in the foecal matter of sewage but through fixation from the air an actual increase takes place over what can be recovered from the sewage." He bases this assertion on various experiments carried out by himself and co-workers. These experiments which are described in some detail in the reference cited, we have summarized below.

(1) Experiments in which 50 cc. portions of activated sludge were aerated with and without the addition of 1 per cent glucose showed 3.3 per cent of combined nitrogen in the sludge to which no glucose had been added, and 7.51 per cent in the sludge to which glucose had been added. This experiment is interpreted by Fowler as indicating fixation of nitrogen. The result may, however, be due to the inhibition of denitrification by carbohydrates mentioned by Doryland (loc.cit.). No data is cited to show the total amount of combined nitrogen at the start and finish of the experiment.

(2) An experiment was carried out with activated sludge in a closed flask in which there was evidence of the absorption of gaseous nitrogen. The authors state, however, that the experiment should be repeated with an improved form of apparatus.

(3) In a small scale experiment with activated sludge, operated on the fill and draw plan, Fowler reports a 32.6 per cent gain in nitrogen. He states, however, that "it should be mentioned that the Kjeldahl nitrogen was only determined in the initial and final sludge. Only the ammoniacal and the albuminoid nitrogen were determined in the sewage added and in the effluent. It is possible, therefore, that the value given for the gain in nitrogen may in consequence be somewhat too high, a greater proportion of Kjeldahl nitrogen being present in the sewage added than in the effluent passing away."

(4) In another experiment in which complete analyses of influent and effluent nitrogen were made, the apparent gain or fixation was only 4 per cent.

(5) Experiments in which a substrate designed to favor nitrogen fixing organisms was inoculated with dried activated sludge and aerated, showed 15 per cent to 25 per cent fixation. On account of the small scale on which the experiments were carried out, the amount of nitrogen fixed was from .004 to .007 gms. The analytical methods are not given.

Fowler interprets Ardern's data as indicating nitrogen fixation. Ardern, however, does not mention such an interpretation of his results. The evidence that there is fixation of nitrogen in the activated sludge process as presented by Fowler seems to be open to question. Our results and those of Richards and Sawyer[52] fail to give evidence to that effect. Certainly further investigation of the question is needed.

That fixation of nitrate and ammonia nitrogen by means of their synthesis into the insoluble microbial protein of the floc, occurring in the activated sludge process seems to be pretty well demonstrated, however.

In the earlier experiments of the activated sludge process considerable attention was paid to the amount of nitrification, that is, of oxidation of organic nitrogen and ammonia to nitrates. Under such conditions protein synthesis could not, of course, be detected. Metcalf and Eddy[28], quoting Hatton and Copeland's[29] work, report that in experiments at Milwaukee using as little as .67 cubic feet of air per gallon, clarification was obtained but no marked stabilization of the sewage. Reference to the table of data in the article cited above shows that using so small an amount of air there was a complete reduction of nitrites and a 50 per cent reduction of nitrates. By using enough air so that decided nitrate formation was produced these workers obtained a clear and stable effluent. Their data does not, however, indicate the fate of the nitrates.

Our experience[53] with low quantities of air using sewage much higher in nitrates than the average, has shown that this nitrite oxygen may be utilized as a source of oxygen by the micro-organisms in the sludge, while at the same time an effluent of reasonable stability is obtained.

Table XI gives the amounts of nitrate and nitrite reduced during the successive periods of operation. As a matter of interest we have recalculated this oxygen in terms of cubic feet of oxygen and free air per 1,000,000 gallons. While this represents only a very minute fraction of the air used in maintaining the activated sludge process, it will be seen that it represents a much larger portion of the air actually required for oxidation of sewage as calculated by Bartow[54],

TABLE XI.

REDUCTION OF NITRATES AND NITRITES.

Date	Duration of Run	Days	Nitrates and Nitrites Inf. p.p.m.	Nitrates and Nitrites Eff. p.p.m.	Nitrates and Nitrites Removal p.p.m.	Nitrates and Nitrites Removal %	Nitrites Inf. p.p.m.	Nitrites Eff. p.p.m.	Nitrites Removal p.p.m.	Nitrites Removal %	NO_3+NO_2 (as N_2) Reduced in lbs. per m.g.	Equivalent in oxygen supplied lbs/ m.g.	Equivalent in oxygen supplied cu. ft/ m.g.	Equiv. in free air cu. ft/ m.g.
May	3-13	11	2.90	1.60	1.30	44.8	0.47	0.36	0.11	23.4	0.1560	0.5351*	5.9°	28.1
"	14-21	8	2.10	0.22	1.88	89.5	0.32	0.05	0.27	84.3	0.2257	0.7741	8.7	41.4
"	22- 1	11	6.40	3.92	2.48	38.8	0.24	0.35	....	....	0.2977	1.0211	11.4	54.3
June	2-15	14	2.20	0.20	2.00	90.9	0.20	0.26	....	....	0.2401	0.8235	9.2	43.8
"	16-30	15	1.00	0.20	0.80	80.0	0.07	0.00	0.07	100.0	0.0960	0.3293	3.7	17.6
July	1-10	10	0.60	0.27	0.33	55.0	0.05	0.00	0.05	100.0	0.0396	0.1358	1.5	7.1
"	15-31	17	0.49	0.12	0.37	75.7	0.04	0.002	0.038	95.0	0.0444	0.1523	1.7	8.1
Aug.	1-15	15	0.80	0.20	0.60	75.0	.06	0.00	.06	100.0	0.0720	0.2469	2.7	12.8
"	16-21	6	0.80	0.10	0.70	87.5	0.02	0.00	0.02	100.0	0.0840	0.2880	3.2	15.2
"	22- 1	11	0.70	0.10	0.60	87.5	0.04	0.00	0.04	100.0	0.0720	0.2469	2.7	12.8
Sept.	2-20	19	1.14	1.61	....	....	0.12	0.76	....	....	......	......	....	....
"	21-28	8	0.70	0.70	0.00	0.0	0.04	0.23	....	....	......	......	....	....
"	29- 6	8	0.60	0.60	0.00	0.0	0.05	0.02	0.03	60.0	......	......	....	...
Oct.	7-16	10	1.00	0.40	0.60	60.0	0.09	0.06	0.03	33.3	0.0720	0.2466	2.7	12.8
"	17-31	15	0.90	0.10	0.80	88.9	0.06	0.00	0.06	100.0	0.0960	0.3289	3.7	17.6
Nov.	16-30	15	6.50	7.00	....	....	0.79	0.90	....	....	......	......	....	....
Dec.	1- 7	7	3.50	1.70	1.80	51.4	0.53	0.19	0.34	64.1	0.2161	0.7403	8.3	39.5
"	8-28	21	4.50	2.00	2.50	55.6	0.43	0.13	0.30	69.8	0.3001	1.0282	11.5	54.7

*14.01 parts of N_2 gives 48 parts of O_2.

°At O°C, 760 mm. Hg., 1 cu. ft. O_2-40.482 gms.-O.08936 lbs.

TABLE XII.

REDUCTION OF NITRATES.

Dec. 14/20 to Feb. 18/21. 63 days.

Illinois Water Survey.

INF.	av.	EFF av.	Flow M. g.p.d.		Air cu. ft. per gal.	
NO_2NO_3	1.56	.787	12/18 to 1/15	100	12/18 to 1/22	1
NH_3	19.6	15.9	1/15 to 1/22	75	1/22 to 2/7	.8
TON	9.95	11.7	1/22 to 2/18	87	2/7 to 2/18	.7

namely, .05 cubic feet per gallon. Table XII gives the summarized figures for nitrates and nitrites during an earlier period. From this table it will be seen that approximately one-half of the nitrite oxygen is utilized in the process.

For the purpose of furnishing another example of the reduction of nitrates by sewage sludge, we have reproduced at this point (Table XIII) a portion of the results carried on at the Lawrence Experiment Station for deodorizing septic sludge by means of nitrified effluent from trickling filters. In this experiment nitrified effluent was

TABLE XIII.

DEODORIZING SLUDGE BY MEANS OF EFFLUENT FROM TRICKLING FILTERS.

Lawrence Experiment Station.

Effluent applied to Sludge: Parts in 100,000.

1919.

Ammonia			Kjeldahl Nitrogen	Nitrogen as		Oxygen Consumed
Fred	Albuminoid Total	Albuminoid In Solution		Nitrates	Nitrites	
3.00	.45	.26	.81	2.16	.1255	2.76
Overflow from Sludge						
3.51	.35	.25	.64	0.41	.0940	2.38
Effluent applied to Sludge: Parts in 100,000 1920						
2.87	.54	.28	1.00	1.36	.0841	2.94
Overflow from Sludge						
2.92	.36	.24	0.68	0.31	.0603	2.23

run into a tank containing septic sludge. The comparison of the analyses of the liquors added with those of the overflow from the tank shows that about 75 per cent of the nitrate oxygen is used in stabilizing the sludge.

In the Dorr-Peck tank a somewhat similar condition exists on the tray or floor of the sedimentation chamber. It will be recalled that the sludge settles out from this tray, but is in contact with the freshly aerated liquor from the aerating chamber. The sludge on the tray consumes the nitrate oxygen. (For further references see Porter's Bibliography, Nos. 160, 224, 244, 384, 528, 530, 535). From the ammonia data in the upper table it will be noted that there is an appreciable reduction of free ammonia.

As may be seen from Fig. 4 there is an appreciable decrease in both free and albuminoid ammonia in the effluent, which is practically independent of the amount of air used. It is interesting to note, however, that when the air amounts to one and a half cubic feet per gallon the effluent and influent curves for nitrates cross—in other words, at this point nitrification takes place. Again, on reducing the air to one cubic foot per gallon there is a reduction of nitrates. This data leads to the conclusion that in the experiments reported in this paper the nitrification phase of the activated sludge process is entirely absent, and that nitrification is not essential to the success of the process. It is apparently possible under some conditions to produce clarification and reasonable stabilization of sewage operating with so little air that nitrate oxygen in the raw sewage is actually consumed by the micro-organisms of the sludge. Attention should, however, be called to the fact that one maximum in the stability curve occurs simultaneously with the maximum influent nitrate and the other with the maximum air.

From the discussion of denitrification we see that there is abundant evidence that nitrates and ammonia are taken up by the organisms of the sludge and synthesized into protein rather than being lost as gaseous nitrogen. Protein formation must have occurred in our experiments, otherwise our nitrogen balance sheet would have shown a loss.

In the article by Richards and Sawyer cited above the conclusion is also reached that the biochemical reactions in this phase of the nitrogen cycle result in protein formation. Their summary is quoted:

"1. If activated sludge is aerated for a short period in an ammoniacal solution the recovery of nitrogen is quantitative. The nitrogen not found as ammonia or nitrate in the effluent is recovered in the sludge.

2. If aeration is continued loss of nitrogen occurs. The loss is roughly inversely proportional to the volume of sludge present.

3. The same effects are observed with sewage. The ammonia falls while the sludge gains nitrogen with a loss of nitrogen on the whole balance after sixteen days operation.

4. There is considerable evidence that the extra nitrogen in activated sludge, over and above that found in the old type sludges, is derived from the ammonia of the sewage. There is no evidence of fixation of atmospheric nitrogen.''

The straw filter for sewage purification used by Richards and Weeks[55] takes advantage of this reaction. They state that: ''Laboratory experiments have shown that about 72 per cent of the nitrogen content of sewage can be recovered by filtration through wheat straw at the rate of 250 gallons per cubic yard of straw per day. The best results were obtained after twenty days when the straw had become activated by bacteria present in the sewage. Operations on a larger scale showed a recovery of 65 per cent of the nitrogen content of the sewage, the resulting manure being odorless and containing 2.06 per cent of nitrogen.''

Summary. 1. An effluent of reasonable stability can be obtained without using air sufficient to produce nitrification.

2. Denitrification results in protein formation rather than in loss of nitrogen.

3. There is apparently no loss of nitrogen when using a minimum amount of air for aeration.

4. There is no evidence of nitrogen fixation even when treating with $FeSO_4$ to stimulate crenothrix like organisms.

CHAPTER VI.

MICROBIOLOGY AND THEORY OF ACTIVATED SLUDGE.

By A. M. Buswell and H. L. Long

In reviewing the opinions of experimenters with regard to the theory underlying the activated sludge process of sewage disposal one soon comes to the conclusion that two main lines of action are held responsible for the results obtained. That the mechanism of the reaction is sometimes described as that of adsorption of the colloidally dispersed matter by sludge already present in the sewage is evident from the following statement quoted from well known authorities:[56]

"The sludge embodied in sewage and consisting of suspended organic solids, including those of a colloidal nature when agitated with air for a sufficient period, assumes a flocculent appearance very similar to small pieces of sponge. Aerobic and facultative aerobic bacteria gather in these flocculi in immense numbers, some having been strained from the sewage and others developed by natural growth." In other words, the usual suspended particles in sewage grow by the accretion of material colloidally dispersed, thus producing activated sludge.

Other writers refer to the "scrubbing action" of suspended particles, and compare the action of activated sludge to that of coagulated alum.[57] The process is often referred to as one of oxidation, assuming that oxidation is a principal step in the purification of sewage. Another definition states that activated sludge must be of "a character to absorb colloidal matter," and another author refers to the "clotting"[58] of the colloids in the sewage. Such expressions seem to indicate what might be called a colloidal or mechanical theory for the mechanism of the action of activated sludge, similar in many respects to the Hampton doctrine of the action of sewage filters. Ardern[59] summarizes the latter as follows: According to this theory the purification process is primarily and essentially a desolution effect brought about purely by physical causes; any bacterial or biological action is definitely ancillary.

Another theory which in reality seems to have been the first to be prepared, is what might be called the biological theory and resembles Dunbar's theory of sewage filters. Those[60] emphasizing this viewpoint of the action of activated sludge call attention to the

analogy between the action of slate beds, contact beds, and sprinkling filters and the action of activated sludge. The sludge is referred to by these writers, not as a clotted, agglomerated or coagulated sludge produced by the mechanical growth of suspended particles in the sludge, but as biological growths arising from the germination and propagation of micro-organisms whose "spores" are always present in sewage. The term "cultivated sludge"[61] used by one author, contrasts perhaps as strongly as any with the term "coagulated" or "agglomerated" sludge, used by those favoring the colloidal theory.

Of the authors who favor the biological theory, we find that some[62] refer to nitrification and nitrifying organisms as requisites for the success of this method of sewage treatment, while others refer to the sludge as being composed of a variety of micro-organisms. Mumford's[63] M7 seems to have been the only specific organism mentioned as having power to produce the purification of sewage. This organism, it will be remembered, required for its best activity appreciable amounts of iron.

If one examines particles of activated sludge under the microscope he is immediately impressed with the fact that there is practically no absorbed, precipitated or coagulated amorphous matter in these sludge particles, but that they are composed entirely of active-growing microscopic organisms of varieties ranging from true bacteria up through the giant bacteria, with occasional molds and yeasts, and also a variety of free swimming and attached protozoa[64]. These communities of micro-organisms must obtain food and this food must be supplied from the colloidal and dissolved matter and salts in the sewage. From what we know of the metabolism of micro-organisms it is probable that the unicellular forms absorb through their membrane such soluble forms of organic matter as are able to pass through this membrane, and that they also secrete enzymes which are capable of peptizing or liquifying colloidal particles too large to be directly absorbed. Protozoa. on the other hand, can easily be seen to approach and ingest visible particles of organic matter. This biological theory of the action of activated sludge may be summarized and emphasized by proposing what seems to be a rather striking analogy, namely, that the purification of sewage effected by microscopic communities appearing as flocs is entirely similar to that of disposal of garbage by feeding it to hogs. It does not seem probable that adsorption of colloids or mechanical precipitation plays any greater part in the metabolism of micro-organisms than they do in the digestion of the larger animals. One serious objection to the colloidal theory of coagulation is that the colloidal particles in sewage

and the activated sludge particles are, so far as we are able to determine, both negatively charged. Since adsorption of colloids is most effective between oppositely charged particles it should not be applied to the conditions of the activated sludge particles without reservation. Furthermore, adsorption is an almost instantaneous action, while considerable time is required for the activated sludge reaction.

Discussion of the theory at this time may seem academic and impractical. Since, however, these two theories would suggest rather different lines of attack on the general problem we have chosen to review and compare them.

If the action is largely colloidal and mechanical, then we shall need to study particularly the colloid chemistry of the sewage. If, on the other hand, it is biological, we should study the biology of the sludge so that we may obtain complete knowledge of the desirable and undesirable members of these microbial communities upon which we are to rely for the purification of sewage.

The biological theory suggests a somewhat different notion of the importance of oxidation in sewage purification than that ordinarily expressed. When garbage is disposed of by feeding to hogs, only as much oxidation takes place as is required to furnish energy for the life processes of the hogs. Final oxidation does not take place until the pork chops are eaten and burned up in the body to furnish human energy. If the analogy of this process to sewage disposal is admitted, oxidation appears as an incidental reaction. Clark,[65] in 1912, called attention to this viewpoint in the following manner: "In experiments upon aeration of sewage tried during the past twenty-five years by various investigators, as described by Drown, Dupre and Dibdin, Mason and Hine, Black and Phelps, etc., the chief object of each study has been to learn the oxidation changes induced by such treatment. The collection of suspended and colloidal matters, as here described, is an entirely new feature of aeration work."

Comparatively little has been published on the organisms of activated sludge. Earlier writers make special mention of nitrifying bacteria; Bartow and Smith[66] noticed at times in the sludge large numbers of worms (Acolosoms Hemprichii) as well as Vorticella and Rotifera. Purdy[64] counted the various protozoa in strawboard waste activated in a three inch glass tube and fed by the fill and draw method.

More recently Dienert[67] and Cambier[68] have debated the role of bacteria in the activated sludge process. Dienert maintains that bacteria are essential since nitrification did not take place in the presence of phenol. Cambier on the other hand maintains that the

aetivated sludge process is an example of ordinary chemical eatalysis. His conslusions appear to be based on three experiments; one in which ehloroform was introduced with the air used for aeration, apparently on the assumption that the chloroform would be a germicide; one earried out at low temperature (O°-12° C) on the assumption that nitrifying baetcria are not active at these temperatures; and one in which iron sulfide was added. That nitrifieation and purification were aeeomplished under these conditions, Cambier interprets as proof of the catalytie theory of the reaetion. He presents, however, no definite data to show sterility of his solutions. In the same journal Courmont[69] reports a study of the bacterial flora of aetivated sludge effluent. He found seven species, one of whieh was B. Subtilis. No obligatory anerobes were found, and in some cases B. Coli was absent.

Riehards and Sawyer[52] have reeently presented data ineluding chemical analyses, bacteria counts and mieroscopie determinations of the number of protozoa. A relation was established between the number of protozoa and baeteria, and the high nitrogen in the aetivated sludge was attributed to synthetic living protein of the bodies of bacteria and protozoa. Under certain conditions of aeration free ammonia and nitrates were synthesized into proteins, as eontrasted with the formation of free ammonia and nitrates which is ordinarily observed in the activated sludge proeess.

Of the various investigations whieh have been made, that of Purdy[64] furnishes the most eomplete data on the various organisms present in the sludge. Purdy followed the usual Sedgwiek-Rafter method of enumerating the microscopie organisms, reporting the zoogleal flocs in standard units of 0.004 mm. sq. Purdy used a 500 ee. aerating vessel operated with an unmeasured excess of air on the fill and draw system with twenty-four hour aeration periods. This system served admirably the purposes of the partieular investigation whieh showed the presenee of relatively large numbers of protozoa, espeeially of Peritrichs. Some work of the present authors on a similar scale and with excess of air and twenty-four hour fillings gave similar results. They do not seem to eorrespond to results obtained when smaller amounts of air are used, nor with the results on larger experimental units.

The analytical data herewith reported refer to samples taken from the aeration chambers of a two tank Dorr-Peek activated sludge unit fully described elsewhere.[53] For the purpose of the present artiele it will be sufficient to state that the apparatus was treating about 65.000 gallons per day in two aeration chambers having capac-

ities of 14,400 and 12,700 gallons respectively and operated in series. Approximately 0.75 cubic feet of air was used per gallon, of which two-thirds was used in the first tank and one-third in the second. A good degree of clarification and an average methylene blue stability of three days were obtained during the run.

Experimental. Microscopic observation made during the winter of 1920-21 indicated that some sort of a relation existed between the amount of air used, the strength of the sewage, the settling rate of the sludge and the types of organisms composing the sludge. When after a shutdown for repairs, the plant was started up in the spring without any activated sludge as a "starter," daily microscopic observations were made to follow the changes in microbial life as the sludge built up. The daily records, which on account of the unexpected pressure of the other work, had to be limited to brief observations, are given below. In general it is to be noted that the Holotrichs were the first to appear in noticeable numbers, but that they gave way in time to other forms. The Peritrichs (Carchesium and Vorticella) appeared only after several days of aeration. The matured sludge seemed to be composed largely of zoogleal masses with frequent colonies of Peritrichs and occasional Hypotrichs (generally Euplotes).

Summary of Microscopic Observations May 3-17, 1921.

May 3.		Plant started operation.
May 4.	I.	A few Paramecium, paper fibres and miscellaneous vegetable cells.
	II.	Same as under I (May 4.)
May 5.	I.	Paramecium, paper fibres and miscellaneous vegetable cells.
	II.	Zoogleal masses of fine bacterial filaments beginning to form.
May 6.	I.	Large flocs of zoogleal mass of fine bacterial filaments.
	II.	Zooglea, Paramecium, Colpidium.
May 7.	I.	Branching zoogleal masses of fine bacterial filaments Paramecium, Spyrogyra.
	II.	Paper fibres with much attached zooglea. Many Paramecium, few Peritrichs (Vorticellidae), branched zoogleal masses of fine filaments.
May 8.	I.	Branched zoogleal masses of fine bacterial filaments, Paramecium, Colpidium, 1 filament of Spyrogyra.
	II.	Branched zoogleal masses of fine bacterial filaments, few Holotrichs, mould hyphae and paper fibers.
May 9.	I.	First appearance of Peritrichs in I. One filament of Spyrogyra, zoogleal masses of filamentous bacteria.
	II.	Increase in Peritrichs.
May 10.	I.	Few ciliates, 80% of field consists of zoogleal masses.
	II.	Many Peritrichs.
May 11.	I.	Largely zoogleal masses of filamentous bacteria, some Hypotrichs and Peritrichs.
	II.	Largely zoogleal masses of filamentous bacteria, fewer Peritrichs.
May 12.		No change in character.
May 13.		Increase in Peritrichs.
May 15, 16,17		No change in character.

In September the daily qualitative study of the sludge was resumed and a careful investigation was made of the forms in the zoogleal masses. In November an interruption in the operation of the plant offered another opportunity to study the forms appearing during the building up of sludge. In this series of examinations, which dates from November 17, quantative estimates were made, using, as Purdy did, the Sedgwick-Rafter method of enumeration. Beginning with the 9th of December, $FeSO^4$, equivalent to 10 mg. per liter of Fe, was added to the influent sewage for the purpose of determining its effect on the nitrogen cycle. It appeared to have no effect on the character of the organisms found. The results of these examinations are given in Tables XIV and XV.

Discussion of Data. A study of the microbiology of activated sludge in its development from raw sewage shows a definite succession or addition of forms. Beginning with the characteristic microorganisms of raw sewage as it is taken into the aeration chamber, there is a predominance of the minute flagellates and ciliates, with occasional Peritrichs and Holotrichs. In a few days the minute forms diminish in number until they become a negligible quantity, while Peritrichs, Holotrichs, and Heterotrichs increase in number, the Peritrichs predominating throughout. As the minute forms become insignificant, there appear zoogleal masses of the Chlamydobacteriacae and Nematodes, to be followed in a few days by the sudden appearance of Peritrichs. This point then brings us to the characteristic fauna and flora of the matured activated sludge, under the particular conditions of operation employed. Observations on the occurrence of the various group of organisms have been summarized as follows:

Minute Ciliates and Flagellates. The fauna of the samples taken November 17, two days after the beginning with raw sewage, was characteristic of the crude sewage. The minute ciliates and flagellates constituted practically the entire of animal life. These forms continued to predominate in decreasing numbers until the 7th to 8th day when with the gradual formation of the sludge there was a marked decrease, with a predominance of larger forms. From November 22 on through the period of observation, minute forms were present but not in sufficient abundance to enumerate. Perhaps there were more of such forms present throughout the period, but were hidden from observation by the heavy sludge. Of the typical forms present. the minute free-swimming individuals predominated.

TABLE XIV.

TANK 1.

ORGANISMS AND SOLIDS.

Date	Minute ciliates and Flagellates (Thousands per c.c.)	Peritrichia (Thousands per c.c.)	Holotrichia and Heterotrichia (Thousands per c.c.)	Hypotrichia (Thousands per c.c.)	Larger Flagellates (Thousands per c.c.)	Nematoda (Thousands per c.c.)	Beggiatoa Filaments (Thousands per c.c.)	Standard Units Zooglea Masses (Millions per c.c.)	Total Solids Mg/1	Per cent Solids Vol. 1 hr. sed.
Nov.										
17	2,885.0	.10	.30	....	....	....	....	.11	....	..
18	215.0	.30	1.40	....	....	....	.20	.38	2200	5
19	90.0	.60	1.90	....	....	....	.30	.37	2700	7
20	....	.....	....	....	....	....	....	....	....	7
21	17.5	3.70	2.40	....	....	.10	.10	.48	2930	8
22	+	6.70	1.60	....	....	.20	.30	.77	3370	9
23	+	2.70	1.40	....	....	.20	.60	.49	4030	11
24	—	.....	....	....	....	....	....	....	....	13
25	+	8.60	3.60	1.20	....	.10	.30	1.08	4500	15
26	+	14.07*	1.00	1.00	....	.50	.33	.54	4900	18
27	—	.....	....	....	....	....	....	....	....	29
28	+	6.50	3.00	3.80	...	.70	.40	.10	5300	37
29	+	12.85*	6.40	1.80	....	1.00	.80	1.54	5800	48
30	+	8.00	6.40	2.40	....	1.60	.40	1.81	5430	68
Dec.										
1	+	17.10	5.70	3.30	....	1.80	.60	2.06	6140	76
2	+	1.44	5.40	3.60	....	2.40	.90	2.50	7350	78
3	+	14.70	5.40	4.50	....	2.40	1.50	2.56	6480	84
4	....	.....	....	....	....	....	....	....	....	82
5	+	4.00	.60	.80	....	1.00	.40	1.11	6050	78
6	....	3.00	4.80	2.70	....	3.30	1.20	1.70	....	..
7	....	5.00	2.00	2.50	....	1.50	2.00	1.51	5300	75
8	....	6.50	2.00	2.00	5.00	1.50	1.00	2.40	4800	74
9	....	4.00	2.50	1.00	5.00	1.50	4.00	1.71	4410	74
10	....	6.80	1.60	1.60	....	2.00	1.20	1.24	4100	52
11	....	.....	....	....	....	....	....	....	....	64
12	+	7.60	1.20	3.20	4.20	4.00	2.80	2.10	4270	56
13	—	12.00	2.20	4.00	....	....	4.50	1.84	4260	57
14	....	15.00*	....	2.00	10.00	1.00	3.00	1.56	3770	57
15	+	13.00	....	3.00	....	.50	5.00	1.99	4010	59
16	+	5.00	1.00	.50	5.00	1.00	5.50	1.55	3120	58
17	+	1.60	....	....	....	....	.80	.82	3060	55
18	....	.....	....	....	....	....	....	....	....	60
19	+	6.00	....	1.60	....	.80	3.20	1.41	3180	54
20	+	5.20	.40	1.60	....	....	4.40	1.32	2910	56
21	+	4.80	....	.40	....	....	1.20	.82	2660	62
22	+	5.10	....	.60	....	....	3.00	.79	2450	54
23	+	2.40	.40	.40	....	....	1.60	.51	2640	54
24	+	5.00	.40	2.60	....	....	.80	.71	2800	67
25	....	....	....	....	....	....	....	....	....	63
26	+	17.00*	.50	1.50	....	....	.50	2.39	3650	70
27	+	10.8	1.00	2.60	....	.20	....	.89	3820	61
28	+	12.40*	.60	1.80	....	.40	.40	1.10	....	81

* Colony or cluster of peritrichs present.

+The standard unit is used here as a measure of surface only and =0.0004 mm.sq.

TABLE XV.

TANK II.

ORGANISMS AND SOLIDS.

Date	Minute ciliates and Flagellates (Thousands per c.c.)	Peritrichia (Thousands per c.c.)	Holotrichia and Heterotrichia (Thousands per c.c.)	Hypotrichia (Thousands per c.c.)	Nematoda (Thousands per c.c.)	Baggiatoa Filaments (Thousands per c.c.)	Units Zoogloe-Masses (Millions per c.c.)	Total Solids Mg/1	Per cent Solids Vol. 1 hr. sed.
Nov.									
17	.....	.....	....	....	....	....	.....	....	
18	120.0	.....	.30	....	.10	....	.043	1370	1
19	63.0	.60	.50	....	....	.50	.098	2360	2
20	....	.....	....	....	....	....	.....	....	2
21	75.0	1.50	.70	....	....	.20	.224	1390	2
22	12.5	2.90	.80	.10	....	.30	.132	1410	3
23	+	1.10	.40	....	....	.20	.231	1370	2
24	....	.....	....	....	....	....	.....	....	3
25	+	.10	1.10	....	.30	.40	.205	1120	2
26	....	.90	.80	.20	.10	.20	.185	1220	2
27	....	.....	....	....	....	....	.....	....	2
28	+	1.20	.50	.20	.10	.10	.145	1050	2
29	+	.50	1.00	....	.10	.10	.055	900	1
30	+	.50	.30	.10	.10	.30	.119	870	0
Dec.									
1	+	.60	.10	....	....	....	.024	890	..
2	+	.10	.40	....	.10	....	.026	780	..
3	....	.....	....	....	....	....	.....	790	..
4	....	.....	....	....	....	....	.....	....	..
5	....	.....	....	....	....	....	.....	1160	4
6	....	5.10	.60	.90	.90	....	.725	....	27
7	....	8.00	.40	2.40	1.20	.40	1.270	3970	60
8	....	3.80	.70	1.30	.40	.10	1.912	4570	64
9	....	4.10	.70	.40	.90	.20	.540	4610	62
10	+	2.80	.30	.70	.40	.50	.312	4780	74
11	....	.....	....	....	....	....	.....	....	60
12	+	13.20	.40	2.40	2.40	2.40	2.010	4460	70
13	+	16.00	7.50	5.50	3.00	2.50	3.400	4630	75
14	+	16.50	.50	2.50	2.50	3.50	2.012	4550	75
15	+	9.50	.50	5.00	2.50	1.50	1.987	3990	69
16	+	9.00	....	....	1.50	3.00	1.712	4030	75
17	+	7.60	.40	.40	.80	1.60	1.500	3450	82
18	....	.....	....	....	....	....	.....	....	82
19	+	6.00	.80	5.60	.40	1.20	1.170	3610	86
20	+	12.4	.40	2.00	....	4.40	2.530	3610	88
21	+	12.40	....	3.60	.40	2.80	2.340	3530	92
22	+	15.00	.90	1.20	.90	3.90	1.192	3270	83
23	+	10.40	....	.80	....	2.60	.840	3000	92
24	+	4.80	....	.40	....	2.00	.675	2690	89
25	.....	....	....	....	....	....	.....	....	..
26	+	3.80	2.20	2.00	.20	.20	1.025	3570	90
27	+	4.80	1.80	2.40	....	.20	1.170	3570	88
28	+	6.40	.80	.80	....	.20	1.405	....	87

INFUSORIA.

Peritrichs. As indicated in the table, the Peritrichs were the most abundant forms throughout the entire period of observation. Beginning with a very low count they reached the point of predominance in eight days, with a count of 14,000 in eleven days, and continued to be the predominating type.

In many cases the extremely high count was due to the presence of colonial forms or to clusters of individuals not colonial.

From December 5 to 16 the Peritrichia were more or less quiescent or encysted. From the 5th to the 10th only very few individuals showed signs of activity; other individuals were largely either quiescent or encysted. From the 12th to the 16th quiescent and active individuals were about equal in prominence.

The predominating type of Peritrichia were Vorticella. Individuals of the Pyxidium type were quite common on November 29, December 5, 8, and 13; occasional individuals were recorded at other times.

A few colonies of Carchesium were observed. A stalk of Zoethamnium, with its characteristic continuous muscle, while never observed in the unstained sludge, was found on a prepared slide stained with fuchsin.

Colonies and individuals were invariably attached to the amorphous particles of the sludge by means of the more or less long stalk. There were present also occasional free-swimming stalkless individuals resulting from division.

Hypotrichia. After ten days of operation hypotrichs of the Euplotes type suddenly became abundant. No Hypotrichs had been observed up to November 23. On the 25th, the 24th being Sunday, the calculated count was 1200 per cubic centimeter. The count remained in the thousands the remainder of the period, reaching the highest count of 4500 on December 3 and next highest on the 31st.

In habits the characteristic Euplotes type was generally associated with the zoogleal masses of sludge where it apparently found its best forage.

The Holotrichia and Heterotrichia. Organisms of this class principally Frontonia were observed in the first sample taken, though in very limited numbers. With the evolution of the sludge they increased to a count of 6400 after fifteen days but showed a marked decrease from this point on, with a total absence in many observations.

There is a similar curve in the unit mass content of the sludge, but the drop is not as sharp as in the case of the Holo and Heterotrichous forms

of the type Genus Podophyra occurred very rarely, while individuals of the type Genus Acineta were quite common. One or two were observed in the field on the following days, November 20, 21, 23, 24, and December 1, 3, 5, 6, 19, 21 and 28.

Suctoria. Suctoria of two types were observed. Individuals

THE WHEEL ANIMALECULES.

Rotatoria. The Rotifers were so rarely observed during the forty-six days that they hardly deserve mention. As the concentration of the sludge increased from the beginning of formation to the climax, apparently the conditions were not suitable for the life and multiplication of the Rotifers. In the small scale experiment, however, carried on with large amounts of air in the laboratory and at the plant Rotifers became more abundant as the sludge became heavier and more concentrated.

In the small scale sludge experiment a much heavier sludge developed because only the effluent was removed. This condition seemed to be favorable to the Rotifers.

The forms most common were representative of the Genus Notommata, while individuals of the type Genus Brachionus were also observed.

ROUND WORMS.

Nematoda. The Nematodes were of common occurrence in the experimental sludge after eleven days of operation. In the observations made in the large plant Nematodes were observed on the fourth day and gradually increased to 2400 per c.c. on the eighteenth day, to a maximum of 3300 on the twenty-first day and then a gradual decrease that was comparable to the decrease in the Rotifers.

Zoogleal Masses. Having briefly reviewed the fauna of the sludge, we shall now turn our attention to the sludge proper. On November 17, after two days' operation with raw sewage, units of zoogleal mass numbered 115,000; by November 25, 1,089,500; by December 1, 2,062,500. The count continued ranging between one and two million units throughout the period, a count typical of a climax sludge maintained at the given dilution.

The animal inclusions of the sludge made up a very small part of the entire mass. The base of the sludge was composed of zoogleal masses intermixed largely with filamentous bacteria and occasional zoogleal ramigera.

It appears that the filamentous forms overwhelmingly predominate in the sludge. The literature on filamentous forms is scattered and rather uncertain taxonomically. Therefore a more extended

study of these inclusions and the literature on the subject is being made, which will determine the species of the forms present. Crenothrix polyspora, Sphaerotilus dichotomus and zooglea ramigera were, however, undoubtedly present in large numbers.

Bacterial Surface. Herring[31] long ago pointed out the importance of bacterial surface in sewage purification, though little definite data has been compiled since his paper on the subject. From the table we may obtain a notion of the order of magnitude at least of the sludge surface of the activated sludge process. Let us take a case where two million standard units of zoogleal masses was found per cubic centimeter in the aeration chamber. Each floc must have a lower surface, equal at least to the upper surface, so that leaving out the side surfaces we would have four million standard units of 0.0004 mm. sq. each, or 16.0 cm. sq. of surface per cubic centimeter of volume. This figure does not include the surface of the protozoa or the free-swimming bacteria. If increased by fifty or one hundred per cent it would probably approach more closely the correct value. This would mean a surface of approximately 500.0 square feet of sludge surface in one cubic foot of the aeration chamber.

Summary. In view of previous work of other authors cited and the data of the present article we wish to propose the following statement of the theory of the activated sludge process. Activated sludge flocs are composed of a synthetic gelatinous matrix similar to that of Nostoc, or Merismopedia, in which filamentous and unicellular bacteria are imbedded and on which various protozoa crawl and feed. The purification is accomplished by ingestion and assimilation, by assimilation by organisms of the organic matter in the sewage and its re-synthesis into the living material of the flocs. This process changes organic matter from colloidal and dissolved states of dispersion to a state in which it will settle out.

A calculation from data given indicates approximately 500.0 square feet of sludge surface per cubic foot of aeration tank volume.

CHAPTER VII.

SLUDGE DRYING EXPERIMENTS.

pH Control of Acidification. *(By A. M. Buswell and C. C. Larson.)*[70] Bartow and co-workers, especially Hatfield[71] and Mohlman,[72] have tried the effect of the addition of a variety of chemicals on the rate of sedimentation, filtration, or separation by centrifuging, of activated sludge. They report that acidification was especially beneficial and Hatfield further states that when the acid added is sufficient to pass the Methyl Orange end point the acidified sludge contracts to one-third the volume to which the unacidified sludge will settle in the same length of time, and that the acidified sludge floats on the liquid from which it is separated. The above mentioned investigators also observed that the acidified sludge did not become septic in a short time as did the untreated sludge. The increased filterability of acidified activated sludge had also been observed by Copeland and chemists of the Sanitary District of Chicago. The same difficulties which are encountered at times when one tries to adjust the reaction of bacteriological culture media by adding the amount of acid calculated from titration have been met with in controlling the acidification of activated sludge. Experiments showed that in one case one-third the amount of acid calculated from titration was the right amount to produce the desired result.

The work of Clark and Lubs[73] on the determination of H^+ concentrations in culture media suggested to the authors that a method which would measure the intensity rather than the capacity factor of acidity would be a proper one to employ in controlling such a reaction. Furthermore, the work of Loeb[74] on gelatin led us to expect that activated sludge which behaves in many respects as a gel, might have a point of minimum swelling or maximum contraction, the so-called isoelectric point.

To test the applicability of Clark and Lubs' results and those of Loeb to the problem of dewatering activated sludge, the work here reported was undertaken.

Effect of Acidification and Heat. In these experiments the following procedure was used: Activated sludge was taken as it came from the tanks, allowed to settle for an hour, and the supernatent liquid siphoned off. This gave a sludge with a moisture content

After thirty minutes the cylinders were removed and the volume occupied by the sludge read as accurately as possible. With the aid of a pair of draftsman's dividers a fairly accurate estimate of the volume occupied by the sludge was obtained. The sludge in each case rose to the top of the cylinders, leaving a comparatively clear liquid below.

A pipette was thrust down through the floating sludge and 10 c.c. of the subnatent liquor removed for determination of the hydrogen ion concentration. The ten c.c. portion was placed in a test tube, five drops of indicator added and the color matched with that of freshly prepared standards.

It was assumed that the supernatent or subnatent liquor from the sludge was in equilibrium with the sludge itself. The liquor usually contained some suspended matter, but this did not interfere seriously with the colorimetric comparison.

The results of five of the experiments are given in Table XVI.

TABLE XVI.

EFFECT OF ACIDIFICATION AND HEAT.

Temperature 50° — Time ½ hour

Experiment I.

Number	c.c.N/1 H_2SO_4	pH	Per cent vol. sludge
1	0	6.8	37
2	5	6.5	27
3	1.0	6.1	20
4	2.0	4.5	16
5	3.0	3.0	16
6	4.0	2.7	16
7	5.0	2.3	16
8	6.0	2.0	17
9	7.0	1.7	16
10	8.0	1.4	16

The raw sludge had a pH value of 7.0.

Experiment II.

Samples of the sludge from the following run were removed and the moisture content determined by evaporating on a steam bath and drying at 105° C. for 24 hours.

Temperature 50° C — Time ½ hour

Number	c.c.N/1 H_2SO_4	pH	Per cent vol. sludge	Per cent moisture
1	0	7.4	26	98.23
2	.5	6.4	18	97.13
3	1.0	6.1	15	96.23
4	1.2	5.8	13.5	95.73
5	1.4	5.4	13	95.43
6	1.6	4.8	12.5	95.39
7	1.8	3.3	12	94.85
8	2.0	3.0	12	95.42
9	2.2	2.5	13	95.18
10	2.4	2.5	12.5	95.70
11	5	1.9	11	95.15
Raw sludge				99.49

Experiment III.

Temperature 50° C — Time ½ hour

Number	c.c.N/1 H_2SO_4	pH	Per cent vol. s.udge
1	0	7.0	53
2	.2	6.6	43
3	.4	6.4	39
7	1.2	6.0	30
8	1.4	5.8	27
9	1.6	5.6	26
10	1.8	5.3	25

Experiment IV.

Temperature 50° C — Time ½ hour

Number	c.c.N/1 H_2SO_4	pH	Per cent vol. sludge	Per cent moisture
1	0	6.9	41	98.13
2	.5	6.4	33	.....
3	1.0	6.0	27	.....
4	1.2	6.0	24	96.86
5	1.4	5.8	23	.....
6	1.4	5.5	23	.....
7	1.8	5.3	22	.....
8	2.0	5.1	20	.....
Raw sludge				99.23

Experiment V.

The following run was made in 500 c.c. graduated cylinders and the subnatent liquor siphoned off and turbidity determinations made. It will be noticed that the turbidity of the subnatent liquor reached a minimum at a pH value approximately the same as that of maximum shrinkage, indicating a minimum of dissolution or dispersion of the gel at that point.

Number	c.c.N/1 H_2SO_4	pH	Per cent vol. sludge	Per cent moisture	Turbidity
1	0	6.7	17	97.16	220
2	2.5	6.2	13	.....	195
3	5.0	5.9	11	95.91	195
4	7.5	3.5	10	95.42	95
5	1.0	2.5	10	.....	95
6	12.5	2.3	10	96.23	110
7	15.0	2.2	10	.....	115
8	17.5	2.1	11	95.50	110
9	20	1.9	10	.....	130

of approximately 99 per cent. Equal amounts of the sludge were placed in 100 c.c. graduated cylinders and amounts of normal sulfuric acid varying from 0 to 10 c.c. were added. The contents of the cylinders were thoroughly mixed and cylinders placed in a water bath at 50° C. equipped with a mechanical stirrer to insure uniform temperature. The cylinders were heated to hasten the equilibrium.

When the experiments were carried on in the cold the sludge in the cylinders containing the least acid settled to the bottom, whereas with the higher acid concentration the sludge floated. The change occurred in each case at a pH value of approximately 5.0. Furthermore, there was a marked color change of the sludge itself in both the hot and cold runs. There was a graduation of color from deep black in the tube to which no acid had been added to a light gray in the tubes with the most acid. A sharp change occurred between a pH of 5.0 and 6.0. (Table XVII.)

TABLE XVII.

EFFECT OF ACIDIFICATION.

A similar series of experiments were made without heating but allowing the cylinders to stand in the cold for a longer period of time.

Experiment I.

Time 3 hours

Number	c.c.N/1 H_2SO_4	pH	Per cent
1	0	7.3	61
2	.5	6.8	74
3	1.0	6.2	55
4	1.5	5.7	36
5	2.0	5.0	27
6	2.5	3.2	26
7	3.0	2.6	25
8	3.5	2.4	24
9	4.0	2.3	24

The sludge in tubes numbers 1, 2, and 3 settled to the bottom. That in number 4 separated, but one-sixth settled and the remainder floated to the surface. The sludge came to the surface in all the remaining tubes.

Experiment II.

Time 3 hours

Number	c.c.N/1 H_2SO_4	pH	Per cent vol. sludge
1	0	7.3	52
3	1.0	6.1	35
4	1.2	5.7	31
5	1.4	5.2	27
6	1.6	4.8	23
7	1.8	4.0	22
8	2.0	3.2	22
9	2.5	3.0	20
10	3.0	2.7	22

The sludge in tube number 1 settled; that in tubes numbers 3, 4, and 5 separated, in each case that going to the bottom was about one-sixth of the total. In tubes numbers 6, 7, 8, 9 and 10 the sludge floated to the surface.

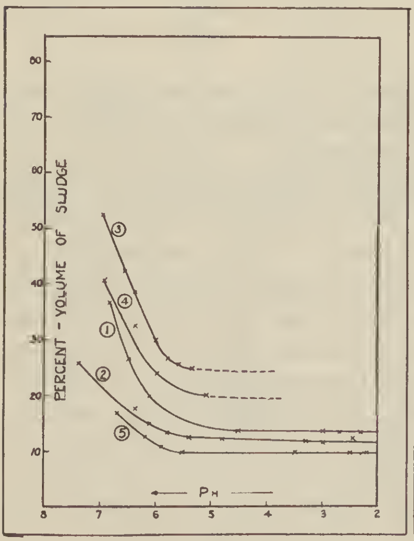


Fig. 26

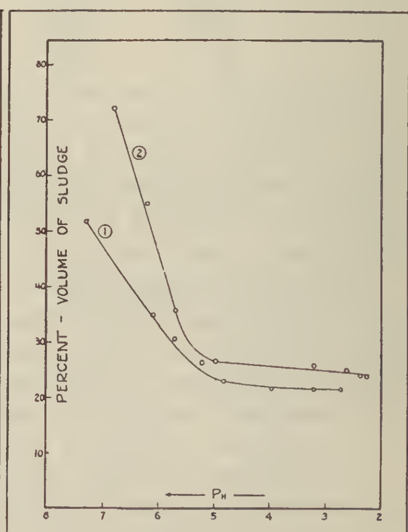


Fig. 27

From the curves (Figs. 26 and 27) it is evident that the volume shrinkage of the sludge is a function of the hydrogen ion concentration, and that a maximum shrinkage occurs at a pH value of approximately 5.0. The addition of more acid does not materially affect its shrinkage, although there is some evidence that an expansion occurs as the concentration of acid is increased beyond a pH value of 4.5.

The phenomenon of floating to the surface is probably due to the action of the acid on carbonates in the sludge and mother liquors liberating minute bubbles of carbon dioxide which buoy up the sludge particles. The specific gravity of activated sludge is about the same as that of the liquid in which it is suspended, as evidenced by its low rate of settling under plain sedimentation. Furthermore, activated sludge after its vigorous aeration in the tanks is thoroughly saturated with air and when the temperature is raised, the dissolved air is driven out of solution and is trapped in the particles of sludge exerting a buoyant effect.

The observations of Hatfield with regard to the sterilizing action of the acid were confirmed. Untreated sludge usually became septic in a few hours, whereas the acidified sludge remained sweet for a much longer period of time.

At first inspection, a reduction of the water content from 99.5 per cent to 95 per cent does not appear very great, and yet if we consider the per cent of dry solids, the actual amount of water eliminated becomes very significant. For the basis of calculation we will consider one ton of dry sludge. As it comes from the tanks this ton of solids will be mixed with water in ratio of about one to two hundred. Upon reduction to 95 per cent sludge the ratio will be one part of solids to approximately twenty parts of water, or, in other words, about 180 tons or nine-tenths of the total water will have been removed. One ton of coal will evaporate approximately six tons of water; in order to effect this reduction by means of heat alone it would require some thirty tons of coal.

The acid necessary to effect the same reduction by the method herein described would cost from fifty cents to one dollar.

Acid-heat-flotation Process. *(A. A. Brensky and S. L. Neave.)* Experiments carried on in this laboratory in November, 1920, by Mr. C. Lee Peck, showed that treatment with acid and heat cause activated sludge to shrink to a comparatively small volume, and that under certain conditions the separated sludge floated to the top of the vessel, forming a fairly compact cake. A small continuous unit for treating sludge by this process was constructed at the Experimental Plant and operated with the co-operation of the State Water Survey. The results obtained were promising, and Mr. Peck obtained a patent upon the method, assigning same to the Dorr Company, by whom he was employed. The "flotation process," as the acid-heat treatment was called, was further used in experimental work carried on by the Dorr Company at New Britain, Conn.,[75] resulting in some improvements in design.

With the permission of the Dorr Company a flotation or frother unit was constructed at our Experimental Plant in November, 1921, and operated from December 16, 1921, to January 6, 1922, to secure partly dewatered sludge (85% moisture) for experiments on further dehydration, especially for experiments with the Bayley sludge drier. Previous experiments in dewatering sludge were tried by pressing, filtering and centrifuging. A Patterson filter press and Oliver continuous filter had proven unsuccessful, and the capacity of our Tolhurst centrifuge was too small to furnish sufficient sludge for the Bayley drier.

The flotation unit was in actual operation for a total number of approximately one hundred hours and furnished an abundant supply of sludge for heat drying experiments.

This process of dewatering sludge may be called the acid-heat-flotation process. It consists of heating a suitable mixture of sludge and acid to such a temperature as to cause the agglomeration of sludge particles to a cake, floating upon an effluent liquor, comparatively low in turbidity. The flotation is assisted by heat since the buoyancy of the cake depends upon numerous minute bubbles of gas liberated in the acidification of the alkaline sludge.

Fig. 28 shows diagrammatically the final arrangement of the flotation unit which consists of a flotation tank, a reaction chamber, a heating system. and flow measurement device. The flotation tank is two feet in diameter and eight feet four inches in depth, the lower part of which is made of concrete and the upper part of twenty-four inch vitrified pipe. The tank is four feet six inches below the ground

surface. In the bottom of the flotation tank and concentric with it is the reaction chamber, one foot in diameter and three feet three inches in depth, made of galvanized iron. Around the reaction chamber, forty feet of half inch pipe forms a heating coil. A small boiler supplies steam for heating. The inlet to the unit is through a one inch cast iron pipe in the bottom of the reaction chamber and the outlet is through a one inch pipe, extending from the bottom of the flotation tank to the effluent control at the top. The lower part of this pipe is outside of the reaction chamber and the upper part is outside of the flotation tank. (Fig. 28.) The sludge and acid rates of

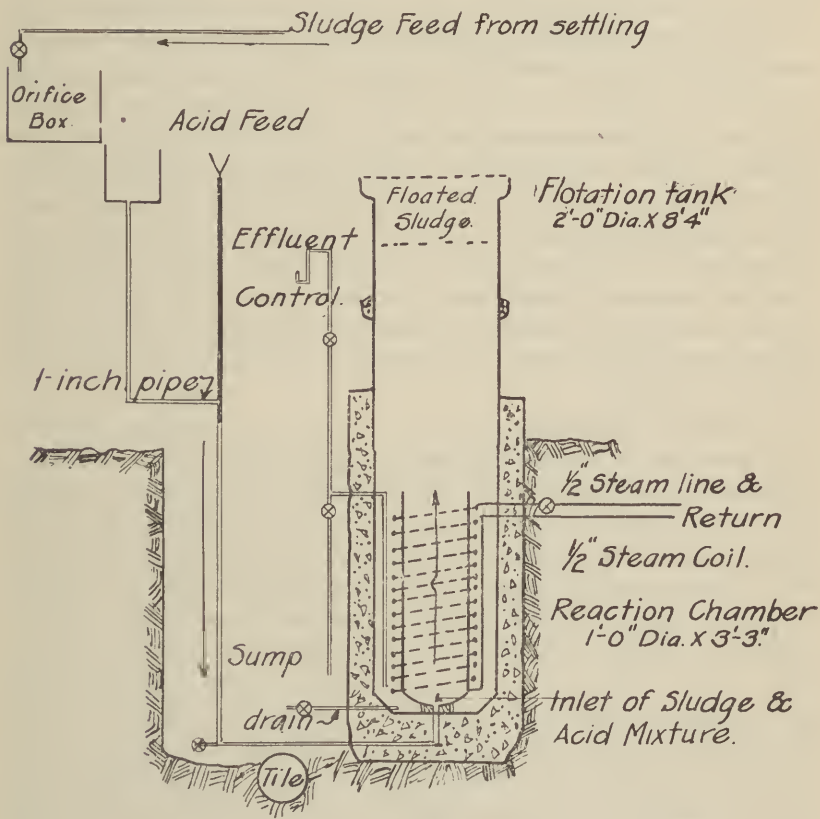


Fig. 28

flow were measured by constant head orifices. The head in the half inch orifice box for sludge measurement was regulated by a hand operated valve.

Activated sludge for the experiments with the acid-heat-flotation process was obtained from both trays of the Dorr-Peck tanks. Sludge

was drawn continuously during the operation of the flotation unit at the rate of from four to eight gallons per minute and allowed to settle in a circular wooden tank of 2300 gallons capacity. The supernatent liquor from this tank overflowed the periphery at the top, and the settled sludge for flotation was drawn from the bottom. When the frother unit was not in operation, the sludge was kept fresh by air diffused through a filtros tile set in the bottom of the tank.

Acid for the experiments was prepared in the laboratory. Commercial sulphuric acid (94%-96% strength) was diluted to a ten per cent strength, and was carried to the plant in five gallon carboys. The handling and regulating of the acid was very satisfactory.

The settled sludge and sulphuric acid flowed separately to a point five to six feet from the inlet to the reaction chamber, where they mixed. The mixture entered the bottom of the reaction chamber and was heated by the surrounding coil as it flowed upward through the chamber. Here the reaction which effected the coagulation and agglomeration occurred. As the contents left the reaction chamber the sludge particles rose and joined the floating cake or natant sludge. When the level of the sludge cake reached the top of the flotation tank, the subnatant liquor was discharged through the one inch effluent control pipe. The height of natant sludge depends upon the subnatant liquor level, which is regulated by raising or lowering the effluent control pipe.

When the sludge cake became from twelve to eighteen inches in thickness part of it was skimmed off, or the entire cake was allowed to build up in the tank until the turbidity in the effluent indicated excess accumulation of sludge particles. By removing part of the sludge cake, a clear effluent was again produced with continued operation. When continuing a run from the previous day all but about twelve to eighteen inches of the sludge was scooped out. The top part of the sludge cake was drier than sludge continuously skimmed. Most of the sludge cake was spread on a wooden platform covered with burlap sacks, and drained for twenty-four hours or more. Water amounting to one-fourth to one-third of the original weight of freshly floated sludge was lost by drainage. In an experiment on sludge draining the entire content of one day's flotation was spread eight inches thick on a cinder bed covered with burlap sacks. After forty-eight hours the sludge depth was less than six inches.

The increasing demand for securing sludge to operate the Bayley drier limited experimentation with the unit to a few days. Some attention was given to securing a more buoyant natant sludge so as to obtain a drier cake from the flotation unit. A central heater placed

inside of the reaction chamber was tried, but no better results were observed. Large bubbles caused the cake to break at the surface and allowed the minute bubbles to escape. A truncated cone made of galvanized metal was placed in the top of the frother tank, so as to secure the entire buoyant effect on a smaller area. No noticeable improvement resulted and the cone was removed.

As nearly as could be determined with the limited time of experimentation, and with the assistance of former experiments, the best conditions of operation for securing the maximum quantity of dewatered sludge were: (1) Rate of feeding settled sludge was from 1.6 to 2.0 gallons per minute. (2) Rate of feeding sulphuric acid was from 100 to 120 c.c. per minute. This rate gave a pH of the effluent between 4.6 and 5.0 (colorimetric tests). (3) The temperature of the effluent liquor was maintained between 48° and 52° C.

These conditions were maintained for the remaining period of operation. When feeding more than 2.0 gallons per minute of sludge to the flotation unit the separation of the natant sludge particles and subnatant liquor was not complete. A sample of the effluent after remaining quiescent for a minute or two, would have a clear subnatant liquor and a thin layer of floating sludge. Effluents with turbidities varying from 20 to 50 parts per million were obtained under good operating conditions and with the rate of feed less than 1.8 gallons per minute.

The desirable hydrogen ion concentration of the effluent was found by previous experiments to be from 4.6 to 5.0. Some interesting observations with other pH values were made. On the first test, with the pH about 6.0, heavy sludge particles discharged with the effluent. Apparently, the acidification was not sufficient for complete flotation. During the last test an excess of sulphuric acid was added. (Pet-cock was opened accidently during the changing of bottles.) The excess acidity caused the breaking up of the sludge cake by comparatively large gas bubbles.

In an effort to secure the necessary drainage of floated sludge before discharging, the effect of variation of temperature was observed. The temperature varied from 40° C to 65° C. The best separation occurred at approximately from 48° C to 55° C. Temperature of 65° C to 70° C caused a very characteristic puncture through the center of the cake. The temperature of the cake below the surface was always a few degrees higher than the effluent.

Chemical results of a run on December 16, 1922, are as follows:

	Sludge Feed	Sludge Cake	Effluent
Moisture	99.2	92.9 (freshly floated)	
Total Solids			1160 p. p. m.
Total Organic Nitrogen	472.1 p. p. m.		2.8 p. p. m.

The physical characteristics of sludge obtained from acid-heat-flotation process changed with time and with the manner of treatment. The freshly floated cake was very loose and wet. Clear water was visible in the fibrous mass quite separate from the sludge particles themselves. The sludge was amenable to drying by drainage and required about three days. With the appearance of dehydration cracks on a bed of sludge within a day or so, the physical characteristics changed from a loose mass to a gummy and putty consistency, stiff and gritless.

On December 17, 1921, samples of freshly floated sludge were left on a cinder bed in the open under all weather conditions. A sample examined a week later resembled a fine sponge. On compressing the mass clear water was expelled. A sample from the same bed examined in February was loose, soft and very spongy. When the material was pressed no free water was expelled and it expanded again to almost its original volume.

The entire process of flotation and drying on beds was free from offensive odors. The material did not deteriorate at a time when the temperature was higher than normal room temperature most of the day for over a week. At present. March, 1922, sludge stored in wooden boxes, a vitrified pipe, and a steel tank, is in practically the same condition as when first stored. Winter conditions have been favorable to good results in the storage of the sludge.

The need of large quantities of dewatered sludge for the Bayley drier, and the uncertainty of the duration of such experiments, made it necessary to store the maximum amount of sludge. Considerable wet sludge with a moisture content of from 96 to 98 per cent was poured on a cinder bed indoors, and drained to about 85 per cent moisture. Freshly floated sludge had a moisture content of about 88 to 92 per cent, which readily drained to about 85 per cent. During the 100 hours of actual operation of the flotation unit, all floated sludge produced was drained and weighed. When stored, the sludge weighed about two tons and had a moisture content of approximately 85 per cent. A sample of sludge taken to the laboratory January 23, 1922, during the operation of the drier, was found to contain 80 per cent moisture.

Some calculations on quantities of coal and acid required for the

flotation unit are made for such conditions of operation as are likely to be met with. With the following conditions, viz., (1) A sludge feed of 98.8 per cent moisture or one-tenth pound of dry solids for every gallon of sludge. (During September 5 to 10, 1921, sludge of 98.8 per cent moisture was drawn from tray No. 2 of the Dorr-Peck tank.) (2) An increase in temperature of sludge from 12° C to 50° C (a difference of 100° Fahrenheit). (3) An effluent with hydrogen ion concentration of from 4.6 to 4.8. (4) A maximum rate of feed of 120 gallons per hour (40 gallons per hour per square foot) a sludge cake of 88 per cent moisture may be floated, which after twenty-four to forty-eight hours drainage would reduce to 83 per cent moisture.

Coal with 10,000 B.t.u. per pound available for heating would produce approximately eight pounds of 85 per cent moisture sludge from feed sludge of 98.8 per cent moisture. (One pound of good coal contained 14,000 B.t.u.) This may be stated as follows: It would require five-sixths pound of coal to float one pound of sludge, on the basis of dry sludge. Using 60 c.c. of ten per cent sulphuric acid per gallon of sludge feed, it would require 0.14 pounds of acid per pound of dry solids produced.

Summing up the relations on the basis of one ton of dry solids, it would require 1,660 pounds of coal and 280 pounds of sulphuric acid for flotation. With coal at $6.00 per ton and sulphuric acid of 94 to 96 per cent strength at $17.00 per ton, the cost to produce sludge by flotation on the basis of a ton of dry solids is estimated to be (a) $5.00 for coal plus (b) $2.50 for acid, or a total of $7.50.

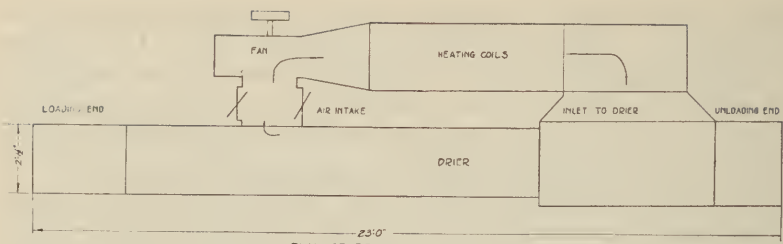
Soon after the conditions of operation were determined, unskilled labor was left at times to operate the entire unit. One man was capable of operating the boiler, changing the acid bottles and observing the temperature and rates of flow.

Conclusions. (1) Experience at Urbana and New Britain has shown that the acid-heat-flotation process works from a mechanical standpoint so smoothly that further experimentation for reducing the cost would be justifiable. (2) Floated sludge is amenable to drying on beds and probably in mechanical filters and presses. (3) Alkaline carbonates in the sludge are apparently necessary for flotation.

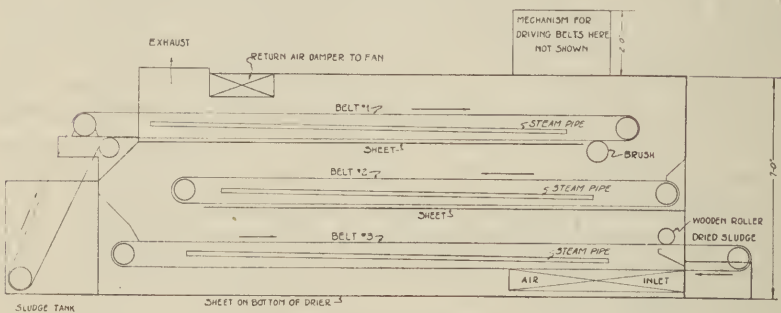
BAYLEY DRIER.

(By G. C. Habermeyer and A. A. Brensky.)

Experiments in drying sludge containing 80 per cent moisture were run with a dryer shown in Fig. 29 which was manufactured especially for these tests by the Bayley Manufacturing Company of Milwaukee.



PLAN OF DRYING APPARATUS



CROSS SECTION OF DRIER

Fig. 29

In this drier the sludge was carried along the upper sides of three endless woven wire belts arranged one above the other, dropping from one end of the upper belt to the middle belt and from that to the bottom belt. At one end of the apparatus the top belt passes through a compartment into which the sludge was shoveled. In this compartment the upper side of the belt, which traveled upward, is inclined at an angle of two and a half vertical to one horizontal. Except for this incline and the turns the belts traveled horizontally. Air drawn from outside or from the drying compartment was forced by a fan through Chinook steam coils and passed to the lower part of the drying compartment in which it circulated in direction opposite to the travel of the sludge. Steam coils were also placed between the top and the bottom of each belt. so that the temperature on any belt could be regulated. Baffles, or partitions, below the two upper belts prevented a direct flow of the hot air upward. Exhaust air not drawn to the blower passed out at the top of the apparatus.

Pulleys, gears, chain drives, belt tighteners, counterweights, canvas flaps to reduce loss of heat at openings, and details are not shown in the figure. Power was furnished by two electric motors, one to drive the belts, and the other of one horsepower to drive the blower. A one horsepower motor to drive the belts was exchanged

for a three horsepower motor on the evening of January 17, after sprockets had been exchanged to increase the speed of the belts. The larger motor did not pull the load and the sprockets were changed back. The trouble was later found to have been due to loose driving gear and unequal tension on two sides of the upper belt. These were adjusted before the run on January 18.

Steam for heating was supplied by a twenty horsepower vertical boiler. This was placed on low ground sixty feet distant from the drier in order to secure circulation without using an injector, but during the experiments returned steam passed through traps to a barrel on a platform scale, and was then returned to the boiler through an injector.

Wet and dry bulb thermometers were placed at the air inlet and air outlet of the drier. Holes were drilled for thermometers in front of the steam coils, beyond the steam coils and above each of the three belts near the center of the apparatus. All temperature readings were centigrade. Readings of inlet air temperatures were of little use as the temperature varied greatly with slight changes in the position of thermometers placed inside of the fresh air intake.

The sludge used in these experiments had been floated, using sulphuric acid and heat as described in an earlier section, and had then been stored in boxes. At the time of tests the moisture content was 80 per cent (the sludge used on January 16 and 17 probably had a moisture content of 80 to 85 per cent.)

On January 16 sludge was placed in the sludge tank and a small amount caught on the belt. The fan operated 660 revolutions a minute. An excellent dried product was secured but in small quantities. From measurements made later it is probable that the rate of feed of wet sludge was less than 10 pounds per hour.

On January 17 the speed of the upper two belts was increased to a little more than one foot a minute, and the speed of the lower belt adjusted to about six-tenths of a foot a minute by exchanging sprockets on the drive and by adjusting gear. The speed of the fan was reduced to 450 revolutions a minute in an attempt to increase temperatures. At the inlet and outlet sides of the fan the pressures were —.15 and + .38 inches respectively.

A sag in the belt affected the feed. At times certain parts would pick up a layer of sludge, and more would adhere to the sides and rivet-heads than to the center. Sludge was carried upward a few inches by the belt and rolled off, with the appearance of a solid roller placed close to the belt. Some sludge was fed by rubbing a stick back and forth close to the belt to prevent this rolling away of sludge. At

other times the sludge was placed on the belt with a small trowel. Results secured were of little value, principally due to poor operating conditions, slipping of belt, breaks, poor adjustment, and consequently over-loading of motor.

On January 18 the gear was adjusted to give a speed to the upper two belts of 1.4 feet a minute and to the lower belt a speed of .82 feet a minute. Adjustments were made to give good operation except for feed of sludge onto the belt.

Sludge was thrown into the sludge tank to be caught on the belt on its travel downward and around the sprockets in the tank, but without success. Some sludge was spread on the belt with a broom, but the rate of feed was low.

During a considerable part of the test the gage on the boiler registered 80 pounds, the air leaving the heating coils was at a temperature of 104° and wet and dry bulb thermometers in the exhaust registered 89° and 40° respectively.

On January 19 the speed of the fan was changed back to 660 revolutions a minute, and the pressures varied from —.33 to —.42 inches at the fan inlet, and from .76 to .68 at the fan outlet. Wet and dry bulb thermometers were placed between the fan and heating coils, and a pressure gage was attached to the heating coils. The boiler pressure could not be held uniform. At times very little water circulated and at other times water was returned from the coils at a rate of 400 pounds an hour. The range of operating conditions is shown by the readings in Table XVIII.

TABLE XVIII.

	January 19			January 20			
Time	12:20 p.m.	4:00 p.m.	5:20 p.m.	3:25 p.m.	4:10 p.m.	4:30 p.m.	4:40 p.m.
Pressure at boiler	75	60	64	48	75	72	60
Pressure at coils	74	56	55	46	69	46	52
Temperature °F—							
Inlet, dry bulb	69°	63	51	51	48	43	46
Inlet, wet bulb	38	31	38	28	27	25	27
Past coils	111	103	100	96	90	88	92
Bottom belt	108	102	101	..	..	..	..
Center belt	109	104	104	..	95	..	95
Top belt	101	98	98	..	..	..	..
Outlet, dry bulb	99	96	96	92	87	..	84
Outlet, wet bulb	44	39	38	36	35	..	36

Water was added to sludge containing 80 per cent moisture, and a small amount of water was found to be of advantage in causing sludge to adhere to the belt, but the amount which adhered was so small that no measurements were made and the experiment was discontinued. An excellent dried product was secured, but in small quantity, as during the first day of the tests.

Sludge was then spread on the belt with a broom, but the rate of

feed was not high and a large part of the sludge adhered to the top belt during more than one complete revolution. The brush placed below the belt near the discharge end was adjusted to give various pressure against the belt, but without success. The small amount of sludge discharged from the machine was very well dried.

Sludge was then spread on the belt with a trowel at a rate of 50 pounds of wet sludge an hour, which was considerably higher than any previous rate of feed. This increased rate was partly due to better adjustment, tighter belt, and a more uniform speed, which was 1.15 feet a minute for the two upper belts, and .68 of a foot for the lower belt. A large part of the sludge adhered to the top belt without falling off, and some large masses accumulated on the brush and then fell to the belt below. Masses one-fourth of an inch thick and more were not satisfactorily dried, and but a small quantity of well dried sludge was secured.

On January 20 the speed of the belts was maintained as on the previous day. As the air at the exhaust was dry and as it was difficult to keep a high boiler pressure, as much air as possible was returned to the fan.

Various methods of feeding the sludge were tried. A box with a slot in the bottom was placed above the top roller at the inlet end of the top belt. Sludge was placed in this box and an attempt was made to regulate the rate of feed with a board held close to the belt to act as a dam, but this was not successful. An opening was then made in the side of the box and sludge was forced through the opening with a wood block, but the sludge was then fed in too thick a layer. Feeding through a slot might have been a little more successful with wetter sludge.

Sludge was placed on the upper belt with a trowel at a rate of 30 pounds an hour. A considerable amount was held on the upper belt for more than one complete revolution.

Wet sludge mixed with dried sludge in the proportion of twenty-five pounds of wet sludge to eight pounds of dried sludge, was fed at a rate of thirty pounds an hour, and the brush was adjusted tightly against the bottom of the top belt. A large quantity of very well dried sludge was secured. The experiment lasted an hour, feeding from 3 to 4 p.m. A large part of the dried material secured was material unloaded from the upper belt, which at the beginning of the test was coated with material adhering to it. During this experiment boiler troubles were at a maximum. Operating conditions are given in Table XVIII.

Mixing 50 pounds of wet sludge with 20 pounds of ashes was

tried. This formed a more uniform and less granular mixture than the wet and dried sludge and apparently was not as successful. It is not directly comparable as the feed was much more rapid in an attempt to secure greater efficiency from the machine. The rate of feed of the mixture was 100 pounds an hour. Temperature conditions during a considerable part of the test are shown above. The drop in temperature in the air (4.40 p.p.m.) was greater than with previous feeds.

Fifty pounds of wet sludge was mixed with five pounds of straw. It was very difficult to secure a good moisture and not a sufficient amount was prepared to run a complete test.

Air circulation was determined by reading an anemometer placed in eight positions in the exhaust opening at the top of the drier. The air discharge with opening twenty-five and a half inches wide and twelve to fifteen inches long was approximately 2700 cubic feet a minute.

Summary. It was difficult to secure sufficiently high boiler pressures at all times.

The sludge could not be fed in the sludge tank and be carried upward on the belt at a practicable rate.

The best results were secured by mixing with a granular material which prevented pressing the sludge into the interstices of the belt and allowed it to fall off from the top belt.

A considerable part of wet sludge applied to the top belt with a broom or trowel adhered to that belt during one or more complete revolutions.

The maximum rate of feed obtained, excepting with the mixture of ashes, was fifty pounds of eighty per cent sludge in an hour.

FILTER PRESS EXPERIMENTS.

(By A. A. Brensky and S. L. Neave.)

A Patterson filter press, Fig. 30, a heavy-duty press of the circular leaf central feed type, with thirty-inch leaves, was used for a brief series of experiments, the results of which are given below. The irregular quality and quantity of sludge obtained from the activated sludge tanks made further filter press experiments seem inadvisable.

A series of ten tests of dewatering activated sludge with a filter press were made during the period from July 8 to 25, 1921. The first test was not recorded; the others have been recorded separately and are appended.

It was found necessary after the first test to place all thirty

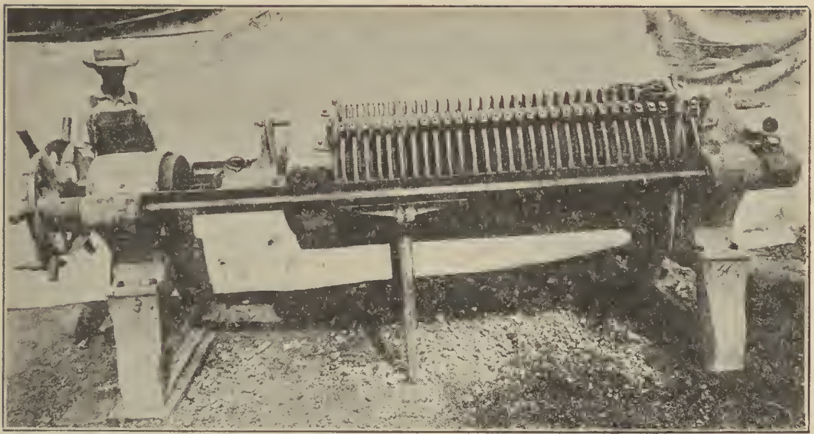


Fig. 30

plates in the press to safely operate. A steel plate, three-fourths of an inch thick, served as a blind to limit the number of plates used. The number used varied from two to six, depending upon the quantity of sludge prepared for pressing, or the possibility of increasing thickness of a cake by decreasing the number of plates.

Preparation of Sludge for Press. About 900 to 925 gallons of sludge were drawn from tray No. 2 of the Dorr-Peek apparatus, and after settling in sludge tank No. 3 for from one to one and a half hours, the supernatant liquid was decanted. The settled sludge was used untreated in the first three tests and acidified in other tests. One hour after the sludge was acidified, most of it floated. This thickened sludge was run into a pressure tank, ready for pressing. In some experiments the sludge remained in the sludge tank over night, while in others it was used immediately.

Conditions of Operation. The pressure was furnished by a duplex air compressor, three and a half bore by four inch stroke. Air was pumped to the steel pressure tank. The valve between the pressure tank and press was opened at the time of starting so that the pressure on the plates varied from zero to maximum. The pressure was controlled by a waste air valve in the pressure tank. The rate of increase of the pressure on the plates varied from one-third of a pound to one and a fourth pounds per square inch per minute. Sometimes the pressure was allowed to remain on the plates after operation ceased, while at other times the pressure was removed immediately and the press opened. In six of the tests leakage between cloths at the periphery of adjacent plates limited the maximum

pressure. It required from three to four men to tighten the plates. The summary of the data collected at the press, and of the chemical results is given in Table XIX.

TABLE XIX.

FILTER PRESS EXPERIMENTS.

July 8-25, 1921.

No. of Test or Experiment.	2	3	4	5	6	7	8	9	10
Gallons sludge drawn from Tray 2.........	900-925 gallons								
Settled sludge after 1½ hours	.....	400	520	465	610	580	580	490	580
C.c. of H_2SO_4 per gal. sludge	.....	.....	1.5	1.5	1.9	2.0	1.7	0.6	0.7
Strength of acid.* Per cent	.....	.....	94	94	90	90	92	92	92
Hours of operation.....	1½	2	1	5	2	2	2	2	2
Maximum rates of flow, g.p.m.	1	1½	6	2.9	1.6	0.6	0.5	.....	0.5
Minimum rates of flow, filtrate after 1½ hrs..	.75	0.7	0.5	0.7	0.6	0.3	0.3	0.3	0.3
No. of plates used.....	6	6	4	4	3	3	2	2	2
Maximum pressure attained, lbs. per sq. in.	85	80	65	110	75	55	50	50	65
Press feed—Moisture %	99.6	99.7	98.8	99.2	99.5	98.6	98.7	99.0	99.0
Press cake—Moisture %	91.2	92.3	90.1	92.5	89.9	87.6	89.5	92.6	90.0
Press filtrate—pH......	.....	.....	6.4	6.4	4.8	4.4	5.0	5.8	5.2
Press filtrate — Turbidity (p.p.m.)..........	68	55	55	100	120	65	75	110	90

Filter Cloth. No. 10 oz. duck filter cloths were used in all of the tests.

Observation. 1. The rates of flow through the press were at a maximum when starting. (Generally when the pressure was below ten pounds.) After the first half hour of operation, the rate of flow rapidly approached the minimum rate as given in the tabulation.

2. The filtrate was clear until a pressure of about fifty pounds per square inch was reached, when the turbidity increased.

3. When opening press to examine the formation of cake, part of the contents was fluid enough to drop or splash out.

4. The thickest cake always formed in the last plate (farthest from inlet), while very little remained in the other plates.

5. The average thickness of the cake over the entire plates was from one-eighth to one-fourth of an inch; over one-half inch sludge cake was generally found at the periphery of all plates.

The length of operation was limited by the rapid decrease of filtration after the first one and a half hours. In some of the tests, the flow decreased to practically zero, even with continued increase of pressure. In test No. 5, after two hours, the rate of one-third of a gallon per minute rapidly decreased to practically zero for the next three hours.

Remarks. The slow rate of filtration was attributed to (a) the clogging of the pores of the filter cloth (b) the pressure on the cloths

forcing the cloth into the corrugations of the plate, thus preventing the filtrate from flowing down between the plate and cloth to the drip holes below.

Two attempts were made to keep the cloth a little distance away from the corrugations by placing first, slats between the plate and cloth, and second, by a circular perforated disk of galvanized iron. (Refer to test No. 3.) In neither case was the effect of increasing the rate of filtration through the press, nor building up a better cake accomplished.

OLIVER FILTER.

Through the courtesy of the Oliver Filtration Company of New York, a laboratory type of continuous filter was at our disposal for a limited time, and some experiments on dehydration of activated

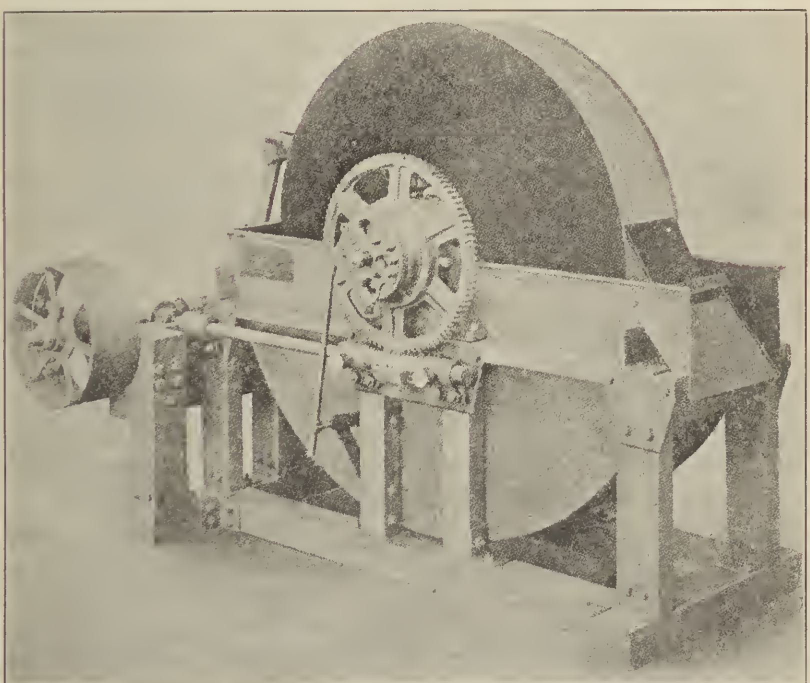


Fig. 31

sludge were conducted early in January, 1921. The machine (Fig. 31) is described in their catalogs. "It consists of a drum or cylinder rotating on a horizontal axis with the lower portion submerged in a tank containing the material to be filtered. The surface of the drum is divided into compartments or sections, the dividing partitions being

parallel to the main shaft. These sections are covered with screen for supporting the filter medium which is held in place and protected from wear by a wire winding. Each of these sections of the drum is connected by means of pipes passing through a hollow trunnion to an automatic valve, which controls the application of the vacuum for forming and washing the cake and also for admission of air for discharging the cake.

"A scraper is fitted across the face of the drum and rests against the wire winding in such a manner that the cake or residue is removed after being released by the air pressure."

Other apparatus furnished by the Company were the vacuum pump, centrifugal pump, vacuum receiver and release valve, moisture trap and other small accessories.

The experiments were confined to sludge previously prepared by secondary sedimentation. In some cases the sludge was acidified cold to a pH of 4.5 to 5.0, and in some cases ground rock phosphate was added. Sludge particles very quickly filled the pores and blinded the filter. Several screening mediums were tried but the same blinding resulted and in no case was a cake obtained.

Part of the work was done with the co-operation of Mr. Tracy of the Oliver Company, who spent several days in our laboratory.

CENTRIFUGE.

In the latter part of December, 1920, a few experiments were made on reducing the water content of sludge as received from secondary sedimentation with a centrifuge. The machinery used was a Tolhurst twelve-inch laboratory centrifuge, equipped with an imperforated basket. The lip of this basket was one and a half inches deep. Vertical vanes attached to the periphery and extending almost to the edge of the lip prevented excessive slipping of the load with sudden change in speed. A speed of 1900 revolutions per minute was used. Sludge entered through a one-inch pipe, dropped to the bottom of the basket, and was thrown to the periphery by the centrifugal force. This force caused the liquid sludge to stand in a vertical wall, the heavier sludge particles collecting on the outside of the wall and the clarified liquor or effluent on the inner side. After sludge had been added, sufficient to occupy all the space under the upper lip, any further addition caused clarified liquor to flow out over the top of the basket. It is apparent that this operation of the centrifuge is in the nature of a sedimentation process in which centrifugal force is substituted for gravity. At the speed used, the centrifugal force was approximately 250 $\times$ gravity. The operation of the machine was

intermittent, the dewatered sludge being removed by hand. Running with a sufficiently low rate of feed to give a well clarified effluent did not produce a firm cake. By increasing the feed as suggested by Professor Bartow it was possible to obtain a cake of 85 per cent moisture, but the effluent contained a large amount of very light, fluffy sludge. At the high rate of feed the weight of cake appeared to be only 15 to 20 per cent of the solids in the sludge.

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APPENDIX.

Sampling and Analytical Procedure.

In general 250cc. samples of the unscreened sewage, screened sewage (tank influent), overflow from the first tank, effluent from the second tank (final effluent) and sludge as drawn were collected hourly by the attendant in charge of the plant. During the earlier part of the experiment samples of the sludge from the settling chamber were collected after drawing a tank of sludge. Other samples, as for example the contents of the aeration chamber and sludge in the peripheral down-cast wells were taken for special microscopic examination and tests on the volume of settleable solids, in accordance with the schedule posted from time to time. Changes in the method and manner of the collection of samples were given in the instruction sheets. The places at which the samples were taken are given in figure 8 and are also indicated on the detailed instructions for collection. The hourly samples were composited at the plant and preserved by the addition of from 5 to 10 cc. of chloroform. Eight of these hourly samples from a given place constituted a "shift composite" so named because they correspond to the three working shifts of the day which ran from 8:30 a. m. to 4:30 p. m.; from 4:30 p. m. to 12:30 a. m.; and from 12:30 a. m. to 8:30 a. m. During part of the experiment some of these samples were further composited in the laboratory before analysis. The procedure of analysis is given below and is also indicated in the tabulations.

Samples of the effluent for methylene blue stability tests were taken at 8:30 a. m., 4:30 p. m. and 12:00 a. m. and were transported to the laboratory for incubation. Settling tests to determine volume of sludge in the aeration chambers and in the peripheral downcast wells were taken from May 3 to December 30, 1921. Four daily samples were taken at 7:00 a. m., 1:00 p. m., 6:00 p. m., and 12:00 a. m. in a liter cylinder and were by necessity settled out at the plant. The settleable solids were expressed as the per cent of the volume of sludge after settling for one hour. A number of tests on settling rates of sludges during the first hour were made from time to time.

Schedule of Tests on Dorr-Peck Activated Sludge Process to Determine (a) Nitrogen Balance or Fertilizer (b) Quality Effluent. December 18, 1920.

1. Sampling arrangements have been made to by-pass a small portion of effluent through the pump house. On the hour 250 cc. samples of effluent and screened sewage are to be added to the bottles designated for the effluent composite and influent composite.

Proceeding in this manner the composite sample of the influent and effluent is to be taken for each shift.

A five-gallon sludge sample is to be taken from the sludge settling tank immediately after sludge is drawn, care being taken to see that it is thoroughly mixed. These samples will be transported to the laboratory in the morning between nine and ten o'clock. A grab sample for methylene blue test is to be taken from the effluent from the second tank at 8.30 a. m. and 4:30 p. m. Methylene blue bottles are brought into the laboratory for incubation. Grab sample of overflow from tank No. 1 is to be taken between 11:00 and 12:00 o'clock and brought into the laboratory at noon.

2. ANALYSES. The two-day shift composites of effluent and influent respectively are to be composited in the laboratory. Samples actually analyzed will consist of:

1. Composite of influent for two day shifts.
2. Composite of influent for night shift.
3. Composite of effluent for two day shifts-
4. Composite of effluent for night shift.
5. Sludge sample.
6. 11:30 overflow sample from first tank.
7. Stability samples at 8:30 a. m. and 4:30 p. m.

The determinations to be made are as follows: (a) First four samples determine free ammonia by distillation and organic nitrogen by Kjeldahl process on residue from distillation; determine $NO_3^- + NO_2^-$ nitrogen by reduction method; determine turbidity. (b) Sample 5, sludge; determine solids settleable in one hour; determine free ammonia, organic nitrogen and nitrates+nitrites as outlined for samples one to four, on supernatant liquid; determine total organic nitrogen on the settled sludge; determine moisture in settled sludge. (c) On sample No. 6 the settleable solids are to be determined by Imhoff cone sedimentation and the turbidity is to be determinel on the supernatent liquid. (d) Stability of sample No. 7 is to be recorded according to Standard Methods.

Schedule of Tests on Dorr-Peck Activated Sludge Process to Determine Amount of Purification and Quality of Effluent with Varying Rates of Flow and Amount of Air.

Beginning February 21st samples will be taken and analyzed as indicated below:

Samples:

A. Unscreened sewage: a composite to be taken for each shift. This composite is made up of 250 cc. hourly samples.

B. Screened sewage: One composite for each shift, taken as above.

C. Effluent: composite for each shift taken as above. Stability samples at 8:30 a. m., and 4:30 p. m.

D. Overflow from tank No. 1: liter sample to be taken at 12:00 p. m.

E. Sludge: a composite sample of sludge to be taken at regular intervals depending upon the rate of flow into the measuring tank.

These samples will be transported to the laboratory between 8 and 9 o'clock in the morning.

TESTS. Samples will be analyzed as follows:

A. The settleable solids (cone) and turbidity on the supernatant liquid are to be determined on each of the shift composites on unscreened sewage.

B. Screened sewage: Settleable solids and turbidity of the supernatant liquid are to be determined on each of the shift composites. After these tests are made the two day shift composites are to be composited and this composite sent through the "sanitary room." The night shift composite is likewise to be sent through the "sanitary room."

C. Of the three effluent samples, the two day shifts composites are to be composited and sent through the "sanitary room." The night shift composite is also to be sent through the "sanitary room." The stability samples are to be transported to the laboratory for incubation and observation.

Samples of overflow from No. 1 are tested according to previous directions.

Schedule of Tests on Dorr-Peck Activated Sludge Process to Determine Amount of Purification and Quality of Effluent with Varying Rates of Flow and Amount of Air.

Beginning March 29 samples will be taken and analyzed as indicated below:

Samples:

A. Unscreened sewage: A composite will be taken for each shift. This composite is made up of 500 cc. hourly samples.

B. Screened sewage: one composite for each shift, taken as above.

C. Effluent: composite for each shift taken as above. Stability samples at 8:30 a. m. and 4:30 p. m. These samples will be transported to the laboratory between 9:00 and 10:00 o'clock, and analyzed as follows:

D. Overflow from tank No. 1: sample to be collected at 5:00 p. m.

E. Sludge samples as before.

TESTS:

A. The settleable solids (cone) and turbidity on the super-

natant liquid are to be determined on each of the shift composites of unscreened sewage.

B. Screened sewage: 100 cc. from each shift sample are to be taken to furnish a 300 cc. sample for T.O.N. Settleable solids and turbidity of the supernatant liquid are to be determined on each of the shift composites. After the operations are complete the two day shift composites are to be composited and this composite sent through the "sanitary room," omitting residue and color. The night shift composite is likewise to be sent through the "sanitary room." Omit residue and color.

C. 100 cc. from each shift sample are taken to furnish a 300 cc. sample for T.O.N. The two day shift composites are composited and sent through the sanitary room. The night shift composite is also sent through the "sanitary room." The stability samples are transported to the laboratory for incubation and observation.

D. Samples of overflow, 5:00 p. m. from No. 1 are tested according to previous directions.

E. Sludge according to previous directions.

Beginning with May 4, samples A, B, C, D, and E are to be collected and analyzed as given in the instruction sheet of March 29. A daily sample of the screenings from the Dorrco screen is to be collected and sent to the laboratory for moisture content determination. (This was only done from July 6 to August 18).

Starting August 22, samples of the sludge in the aeration chamber and in peripheral wells of tank No. 2 are to be collected at 8:30 a. m. and sent to the laboratory for total solids determination. The overflow (sample D) collected at 8:00 p. m. is to be superceded by a twenty-four hour composite taken the same as samples A and B. All other samples were collected in accordance with previous instructions.

Starting September 21 a twenty-four hour composite of the effluent and influent was to be made at the laboratory for analyses and raw sewage samples are to be discontinued. Determination of the total solids of the aeration chamber and tray sludge of both tanks are to be made on a daily composite collected at six-hour intervals. A 250 cc. sample of the aeration chamber content is to be collected at 8:00 a. m. and sent to the laboratory for microscopic examination. Another methylene blue sample is to be taken at 12:00 a. m.

Analytical Procedure. The determinations included settleable solids, (Imhoff cone), turbidity, oxygen consumed ($KMnO_4$), alkalinity, chlorides, total solids, free NH_3, albuminoid N., total organic N, nitrites and nitrates. These determinations were made on all influent and effluent samples. Determinations for nitrogen and solids were made upon the sludge while those for settleable solids and turbidity were made on the unscreened sewage.

The value of such tests as chlorides and alkalinity when ap-

plied to sewage analysis may be questioned. They were included principally to avoid changing the routine of our water analysis laboratory.

Since the laboratory personnel was limited, since furthermore the experiment was concerned largely with determining two factors: first, the quality of the effluent of the Dorr-Peck tank, and second, the amount of nitrogen that could be recovered in solid form, it did not seem advisable to adopt as a routine the Gooch crucible determination of filterable solids. We followed the analytical procedures given in the 1917 edition of Standard Methods of the American Public Health Association.

APPENDIX I.

NITROGEN BALANCE 12/18/20-2/18/21.

Date	Influent: M. Gallons	Influent: $NO_3 + NO_2$	Influent: Free NH_3	Influent: Tot. Org. N.	Influent: Total p.p.m.	Influent: Tot. N. Lbs/Mg.	Influent: Inf. N. Tot. Lbs.	Effluent: M. Gallons	Effluent: $NO_3 + NO_2$	Effluent: Free NH_3	Effluent: Tot. Org. N.	Effluent: Tot. N. p.p.m.	Effluent: Tot. N. Lbs/Mg.	Effluent: Eff. N. Tot. Lbs.	Sludge: Gallons	Sludge: Tot. Lbs. Sl. N.
12/18/20	57,480	.5	22	.2	27.2	.226	12.96	56,586	.2	16.6	6	17.4	.1445	8.16	900	1.699
	33,360	.7	20	5.2	25.9	.215	7.16	33,360	1	23.2	12.4	36.6	.308	10.15	.....	......
12/19/20	64,440	.8	23.2	10	34.0	.282	18.21	63,540	.9	18.4	6	25.3	.210	13.34	900	1.734
	33,360	1.8	18	5.2	25.0	.2037	6.96	33,360	.1	45.6	5.2	31.8	.264	8.80	.....	......
12/20/20	68,780	1.0	23.2	24	48.2	.400	27.5	67,800	.75	23	7.4	31.15	.258	17.52	900	1.889
	34,480	1.5	22	6	29.5	.245	8.44	34,480	.28	22	12	34.28	.284	9.80	.....	......
12/21/20	66,800	.5	33.6	12	46.1	.383	25.57	65,000	.22	23	8.4	31.62	.2625	16.15	1,800	4.17
	35,000	2.0	10	6	18.0	.1495	5.22	35,000	.5	17.2	6	23.7	.1965	6.88	.....	......
12/22/20	66,600	2.0	24	16	42	.349	23.21	63,900	.5	20	18.6	39.1	.3245	20.72	2,700	4.62
	33,300	3.3	8.8	4	16.0	.1328	4.42	33,300	.2	12	10	22.2	.1842	6.14	.....	......
12/23/20	66,000	1.0	20	10	31.0	.257	16.98	63,300	.3	9.4	10	19.7	.1635	10.35	2,700	3.819
	33,000	2.5	10	5.2	17.7	.147	4.85	33,000	.2	15.2	9.6	25.0	.207	6.84	.....	......
12/24/20	66,600	1.3	18	17.6	36.9	.306	20.4	62,100	.28	13	7.69	20.97	.174	10.81	4,500	9.19
	33,000	2.0	13.2	4.4	19.6	.1626	5.37	33,000	.2	16	6.4	22.6	.1875	6.18	.....	......
12/25/20	62,340	.8	22	14.8	37.6	.312	19.45	57,840	.22	15.6	9.2	25.0	.2075	12.01	4,500	8.217
	26,200	1.8	17.2	5.6	24.6	.204	5.34	26,200	.4	18	6.4	24.8	.206	5.49	.....	......
12/26/20	44,680	.7	23.2	14	37.9	.315	15.3	48,680	.24	17	8	25.24	.2095	10.20	.....	......
	32,320	1.8	13.6	4.8	20.2	.1675	5.42	32,320	.2	18	9.6	27.80	.2306	7.46	.....	......
12/27/20	48,000	.77	20	.5	21.27	.1765	8.48	48,000	.26	15.6	10.8	26.66	.221	10.62	.....	......
	17,670	1.4	12	3.2	16.16	.138	2.44	17,670	.28	16	9.2	25.48	.2115	3.74	.....	......
12/28/20	29,400	.68	21.2	11.2	33.08	.2557	7.52	29,400	.3	12.4	8.8	21.50	.1685	5.25	.....	......
	13,800	.6	12.4	17.2	30.2	.251	3.46	13,800	.26	11.2	10	49.60	.412	5.68	.....	......
12/29/20	37,000	.6	20.8	3.6	25.0	.2075	7.68	37,000	.54	13.4	25.8	39.74	.330	12.22	.....	......
	20,180	1.3	14	4.8	41.5	.345	6.96	20,180	.52	14	28.8	43.32	.3599	7.22	.....	......
12/30/20	50,150	.36	21.2	.36	21.92	.182	9.12	40,750	.28	17	29	46.28	.384	15.65	9,400	5.115
	34,200	.8	13.6	5.6	20.0	.166	5.18	34,200	.36	16	26.4	42.76	.3555	12.15	.....	......
12/31/20	67,420	.4	19.6	20	40.0	.332	22.4	67,420	.3	18	10.2	28.50	.2368	15.96	.....	......
	33,640	1.6	9.2	5.6	16.4	.1363	4.58	33,640	.2	12.4	16	28.60	.2375	7.99	.....	......
1/1/21	67,600	2.8	14.8	.8	18.40	.153	10.35	67,600	.91	9.4	9.6	19.91	.1651	11.17	.....	......
	33,400	7.7	8	2.0	17.7	.1470	4.91	33,400	3.6	9.6	8.0	21.20	.1760	5.88	.....	......

APPENDIX I—Continued.

NITROGEN BALANCE 12/18/20-2/18/21

Date	Influent: M. Gallons	Influent: NO_3+NO_2	Influent: Free NH_3	Influent: Tot. Org. N.	Influent: Total p.p.m.	Influent: Tot. N. Lbs/Mg.	Influent: Inf. N. Tot. Lbs.	Effluent: M. Gallons	Effluent: NO_3+NO_2	Effluent: Free NH_3	Effluent: Tot. Org. N.	Effluent: Tot. N. p.p.m.	Effluent: Tot. N. Lbs/Mg.	Effluent: Eff. N. Tot. Lbs.	Sludge: Gallons	Sludge: Tot. Lbs. Sl. N.
1/2/21	67,710	2.0	18	7.2	27.20	.226	15.31	67,710	3.5	13.2	5.2	21.90	.1820	12.3	.....	......
	32,090	4.8	11.2	3.6	19.60	.163	5.22	32,090	.56	16.8	5.6	22.96	.1905	6.11	.....	......
1/3/21	59,300	3.5	13.2	5.2	21.90	.1820	10.80	57,670	2	18	2.4	20.60	.171	9.86	1,630	1.7
	34,700	4.4	10	4	18.40	.1529	5.30	34.700	.28	18	9.2	27.48	.228	7.91	.....	......
1/4/21	65,850	8	24	12	36.80	.306	20.15	65.000	.4	20	2.6	23.0	.1910	12.44	850	......
	32,400	3.6	12	6	21.60	.1795	5.81	32.400	.12	19.2	6	21.72	.1805	5.84	.....	......
1/5/21	66,000	6	23.2	1.2	30.4	.2525	16.65	63,240	.16	19	16	35.16	.292	18.47	2,760	4.147
	33,000	2.8	12	6	20.8	.1725	5.70	33,000	.52	11.2	6	17.72	.1470	4.85	.....	......
1/6/21	67,970	.52	12	16	28.52	.237	15.93	58.900	1.04	18.6	25	19.89	.1650	9.70	8,170	10.61
	34,480	.52	11.2	6	17.72	.1472	5.38	34.480	.16	20.8	12	21.08	.175	6.03	.....	......
1/7/21	66,020	.52	24	16	40.52	.3365	22.22	61.750	.16	18	11	29.16	.242	14.94	4,275	5.817
	31,480	.88	16	.8	17.68	.1468	5.10	31.480	.4	18	1.2	19.6	.163	5.12	.....	......
1/8/21	57,880	.88	24	17.2	42.08	.349	20.20	53,310	.24	18.6	18.2	37.04	.3071	16.4	4,570	2.63
	34.060	2.32	12	5.2	19.52	.1622	5.52	34,060	.36	20	8.8	29.16	.242	8.24	.....	......
1/9/21	66,700	.88	24	17.2	42.08	.349	23.3	63,000	.5	19	4.8	24.30	.202	12.72	3.700	.2535
1/10/21	33,300	2.4	18	5.2	25.6	.2125	7.04	33,300	.4	22	.4	26.4	.219	7.29	.....	......
1/10/21	67,700	.72	24	.2	24.92	.207	14.02	65.000	.18	21.2	21.8	43.18	.359	23.32	2,700	1.702
	36,000	2.4	14	5.6	22.0	.1825	6.58	36,000	.28	17.2	17.2	34.68	.2875	10.35	.....	......
1/11/21	61,800	.8	24	.4	25.2	.209	12.94	60.700	.48	13.6	14.2	27.98	,2321	14.1	900	.561
	34,000	2.32	14	.02	16.34	.1355	4.61	34,000	.28	19.2	5.2	24.68	.205	6.96	.....	......
1/12/21	64,330	.28	24	13.2	37.48	.311	20.0	64,330	.24	19.4	5.14	24.78	.2059	13.23	.....	......
	32,000	1.	18.8	.08	20.6	.171	5.47	32,000	.32	20	.20	20.60	.1713	5.48	.....	......
1/13/21	66,900	.32	20	13.2	33.52	.278	18.6	66.900	.38	28.8	18.6	47.78	.3135	20.95	.....	......
	34,000	1.6	17.2	6	24.80	.206	7.0	34,000	.12	18	22	40.12	.3335	11.4	.....	......
1/14/21	65,490	.4	22.8	19.2	42.50	.353	23.12	65,490	.28	20.4	6.8	27.48	.228	14.94	.....	......
	33,800	2	16	6	24.	.1993	6.74	33.800	.48	22.8	.4	23.68	.1965	6.64	.....	......
1/15/21	71,400	.2	32	18	50.2	.417	29.8	71,400	.44	16	11.2	11.80	.098	6.99	.....	......
	34,800	1	16	8	25.0	.2078	7.22	34.800	.28	19.2	.4	19.88	.165	5.47	.....	......
1/16/21	60,000	.52	28	18	46.52	.3865	23.2	60,000	.28	18	4.2	22.48	.1866	11.2	.....	......
	31,000	2.2	18	4	24.20	.201	6.22	31,000	.28	22	18	40.28	.3304	10.36	.....	......

1/17/21	52,000	.28	28	1	29.28	.243	12.65	52,000	.3	20	15	35.3	.293	15.25	.....	......
	24,000	1	16	2.8	19.80	.1644	3.95	24,000	.28	24	18	25.08	.208	4.99	.....	......
1/18/21	49,000	.2	28	16	44.20	.367	18.0	49,000	.2	20	13	33.20	.276	13.51	.....	......
	25,800	1	18	6	25.0	.2075	5.36	25,800	.2	22	26	48.20	.400	10.32	.....	......
1/19/21	49,700	.52	28	18	46.52	.387	18.95	49,700	.24	19	15	34.24	.2422	12.05	.....	......
	21,600	1.8	16	8	25.80	.2142	4.63	21,600	.2	20	20	40.20	.3325	7.18	.....	......
1/20/21	43,400	.52	24	4	28.52	.237	10.78	43,400	.26	19	17	36.26	.301	13.05	.....	......
	23,000	1.2	18	8	27.20	.226	5.2	23,000	.28	20	14	34.28	.2845	6.54	.....	......
1/21/21	48,200	.4	24	12	36.40	.304	14.56	48,200	.32	19	16	35.32	.2935	14.15	.....	......
	24,500	2.4	12	6	20.40	.1695	4.15	24,500	.2	18	4	22.20	.1845	4.52	.....	......
1/22/21	52,700	.52	22	18	40.52	.2365	17.75	52,700	.54	16	12	28.54	.237	12.50	.....	......
	29,000	2.4	16	2.8	21.20	.176	5.11	29,000	.28	18	16	34.28	.2843	8.25	.....	......
1/23/21	57,700	1	24	12	37	.307	17.72	57,700	.36	18	9.4	27.76	.2307	13.30	.....	......
	29,000	4.8	16	5.2	26	.216	6.26	29,000	.52	20	10	30.52	.2535	7.21	.....	......
1/24/21	58,000	6	22	18	40.6	.337	19.55	58,000	.17	21	6.6	28.30	.235	13.64	.....	......
	28,000	3.6	12	6	21.6	.1795	5.02	28,000	.2	18	12	30.20	.2508	7.02	.....	......
1/25/21	58,600	.92	24	14	38.92	.323	18.95	58,600	3.4	17	17	37.40	.3102	18.20	.....	......
	29,000	2.4	16	5.2	23.60	.196	5.69	29,000	.2	18	14	32.20	.2672	7.75	.....	......
1/26/21	58,300	.92	24	14	38.92	.323	18.85	58,300	.2	17	11	28.20	.2341	13.65	.....	......
	29,000	3.6	14	6	23.60	.196	5.69	29,000	.32	18	16	34.32	.285	8.26	.....	......
1/27/21	56,300	.8	18	12	30.80	.2557	14.4	56,300	.4	16	19	35.40	.294	16.55	.....	......
	28,700	1.4	20	10	31.40	.261	7.48	28,700	.4	20	18	38.40	.319	9.15	.....	......
1/28/21	58,000	1.2	24	13.2	28.20	.234	13.57	58,000	.36	17.6	11.4	29.36	.244	14.14	.....	......
	28,400	2.32	14	14	30.32	.252	7.16	28,400	.4	20	16	36.40	.3041	8.58	.....	......
1/29/21	52,000	.8	23.2	13.1	37.1	.308	16.01	52,000	.23	11	11	45.20	.3755	19.55	.....	......
	29,000	4.8	10	16	30.8	.256	7.42	29,000	.32	16.8	14	31.12	.2582	7.49	.....	......
1/30/21	57,300	2.32	20	8	30.22	.252	14.45	57,300	.5	14.4	10	24.90	.207	11.85	.....	......
	27,000	6.4	9.2	3.6	19.20	.1595	4.31	27,000	.52	14	15.5	30.02	.2497	6.74	.....	......
1/31/21	58,400	1.2	20	14.8	36.0	.299	17.46	58,400	1.16	16.6	15	32.76	.272	15.89	.....	......
	28,800	6.4	12	5.2	23.60	.196	5.64	28,800	.2	12	12.8	25.0	.2077	5.98	.....	......
2/1/21	56,700	1.4	22.8	10	34.20	.284	16.11	54,900	.24	13.4	15	28.64	.238	13.06	1,825	2.734
	29,000	4.4	10	5.2	19.60	.1627	4.72	29,000	.28	14	18	32.28	.268	7.76	.....	......
2/2/21	58,000	1	23.2	20	44.20	.367	21.3	58,000	.2	14.6	18	32.80	.2726	15.91	.....	......
	29,000	2.4	16	9.2	27.60	.229	6.64	29,000	.2	15.2	14	29.40	.2441	7.08	.....	......
2/3/21	58,000	1.4	20	14	35.40	.294	17.05	55,300	.24	14	12	26.24	.218	12.06	2,700	2.85
	29,000	4	14	6	24.	.1994	5.78	29,000	.2	14	14	28.20	.2341	6.79	.....	......
2/4/21	54,800	1	20	10	31.	.2573	14.11	50,300	.24	13	15	28.24	.2345	11.8	4,550	5.00
	29,000	4	12	8	24.	.1993	5.78	29,000	.2	14	14	28.20	.234	6.78	.....	......
2/5/21	56,000	.6	18	14	32.60	.2705	15.15	53,200	.34	12	10.6	22.94	.2421	12.94	2,800	1.53
	28,000	2	12	7.2	21.20	.176	4.93	28,000	.2	14	10	24.20	.201	5.62	.....	......
2/6/21	58,000	1	20	12	33	.274	15.9	57,100	.4	15	14.4	29.80	.2475	14.12	900	1.261
	29,000	2.4	14	8	24.40	.203	5.88	29,000	.28	18	8	26.28	.2180	6.33	.....	......
2/7/21	57,000	1.2	16.	6	23.2	.1926	10.98	57,000	4.4	20	16.6	41.0	.3401	19.4	.....	......
	28,000	4.8	8	8.4	17.60	.1461	4.09	28,000	.2	18	8	26.20	.2175	6.45	.....	......
2/8/21	57,500	1	24	20	35	.291	16.72	55,650	3.4	16	13	32.4	.2691	15.00	1,850	7.22
	28,500	3.2	14	6	23.20	.1926	5.49	28,500	.28	14	8	22.28	.185	5.27	.....	......

APPENDIX I—Continued.

NITROGEN BALANCE 12/18/20-2/18/21

Date	Influent M. Gallons	Influent NO_3+NO_2	Influent Free NH_3	Influent Tot. Org. N.	Influent Total p.p.m.	Influent Tot. N. Lbs/Mg.	Influent Inf. N. Tot. Lbs.	Effluent M. Gallons	Effluent NO_3+NO_2	Effluent Free NH_3	Effluent Tot. Org. N.	Effluent Tot. N. p.p.m.	Effluent Tot. N. Lbs/Mg.	Effluent Eff. N. Tot. Lbs.	Sludge Gallons	Sludge Tot. Lbs. Sl. N.
2/9/21	56,650	1	24	16	41.0	.3405	19.32	53,000	.26	17	14	31.26	.2595	13.76	3,650	5.75
	29,000	4	10	5.2	19.20	.1595	4.62	29,000	.04	16	8	24.04	.2000	5.8	.....	......
2/10/21	58,600	1.2	22	14	37.20	.309	18.12	54,000	23.4	16	14	53.40	.441	23.8	4,600	10.46
	29,000	4	12	8	24.0	.1992	5.78	29,000	.12	14	10	24.12	.2005	5.81	.....	......
2/11/21	58,000	1	22	14	37.0	.3074	17.85	58,000	.44	16	16	32.44	.2695	15.63	.....	......
	29,000	4.8	16	6	26.80	.2225	6.45	29,000	.28	18	10	28.28	.235	6.8	.....	......
2/12/21	55,000	1	20	14	35.0	.2905	15.98	55,000	.4	17	17	34.40	.2856	15.71	.....	......
	28,000	2.4	16	6	24.4	.1995	5.08	28,000	.2	18	12	30.20	.2517	7.01	.....	......
2/13/21	58,000	1	20	12	33	.2740	15.90	58,000	.4	17	14	31.40	.2508	15.11	.....	......
	29,000	2.4	14	6	22.40	.1860	5.40	29,000	.28	20	8	28.28	.235	6.81	.....	......
2/14/21	57,700	.6	20	12	32.60	.2708	15.62	57,500	.5	20	15	35.50	.295	16.97	.....	......
	29,000	2.4	10	5.2	17.60	.1461	4.24	29,000	.2	19.2	8	27.40	.2275	6.6	.....	......
2/15/21	57,700	.4	22	14	36.40	.302	17.42	55,850	2.8	15	14	31.80	.264	14.76	1,850	.8685
	29,900	2.2	12	5.2	19.40	.1611	4.82	29,900	.12	16	10	26.12	.217	6.49	.....	......
2/16/21	59,000	.6	24	16	30.60	.254	15.00	59,000	.16	18	12	30.16	.2505	14.76	.....	......
	29,000	4.8	14	5.2	24.0	.241	6.98	29,000	.28	16	10	26.28	.218	6.31	.....	......
2/17/21	57,200	00	24	14	38.6	.323	18.46	55,400	.12	15	10	25.12	.2086	11.85	1,850	1.266
	30,000	2.4	14	5.2	21.6	.1794	5.38	30,000	.28	18	8	26.28	.2181	6.54	.....	......
2/18/21	58,000	.56	24	14	38.56	.3202	18.6	55,200	.24	15.6	8	23.84	.1971	10.89	2,775	1.56
	29,200	3.2	12	5.2	20.4	.1694	4.95	29,200	.20	18	10	28.2	.234	6.84	.....	......
Totals....	5,556,310						1,423.83	5.468,810						1.417.81	87,205	85.66

Net Loss $N_2 = 0.43\%$.

APPENDIX II.

CHEMICAL DATA.

AVERAGE FOR EACH PERIOD.

Period		Turbidity			Oxygen Consumed			Alkalinity			Residue			Free NH_3			Albumined NH_3			T. O. M.		
Date....	Days Run	Inf.......	Eff.......	% Rv'd..	Inf.......	Eff.......	% Rv'd...	Inf.......	Eff.......	% Rv'd..	Inf.......	Eff.......	% Rv'd..	Inf.......	Eff.......	% Rv'd..	Inf.......	Eff.......	% Rv'd..	Inf.......	Eff.......	% Rv'd..
5/3-13....	11	225	81	64	50.7	31.3	38.2	366	401	....	939	829	11.8	12.5	17.6	....	3.6	1.9	47.3	9.6	4.8	50.0
5/11-21...	8	221	69	69	55.9	31.1	44.4	422	442	....	998	812	18.7	17.0	16.7	1.8	4.4	1.6	63.6	9.2	4.5	51.2
5/22-1....	11	199	42	79	42.0	28.6	31.9	333	365	....	962	856	11.0	9.3	10.0	....	2.0	1.3	36.8	7.1	4.4	38.3
6/2-15....	14	201	39	80	54.2	30.1	44.5	401	410	....	903	817	9.5	12.3	10.0	18.7	3.8	1.5	59.0	11.1	6.8	38.7
6/16-30...	15	249	114	54	65.1	43.5	30.1	443	442	0.3	991	1011	....	17.0	12.9	23.2	4.4	3.4	22.7	12.5	13.1	....
7/1-10....	10	231	143	38	62.1	46.5	25.1	448	447	0.2	986	979	0.8	16.5	13.4	18.8	4.5	4.3	4.4	13.4	16.1	....
7/15-31...	17	242	88	63	56.2	37.4	33.4	437	374	14.4	964	846	12.2	20.0	16.7	16.5	3.6	2.5	30.6	9.5	9.6	....
8/1-15....	15	243	50	79	69.0	35.0	49.3	422	386	8.5	1021	824	19.3	18.7	15.3	18.2	5.2	2.3	55.8	13.7	7.6	44.5
8/16-21...	6	262	33	87	84.0	41.0	51.2	463	400	13.6	1162	847	27.1	21.0	17.1	18.6	5.9	1.9	67.8	21.6	6.1	71.8
8/22-1....	11	302	24	92	54.0	34.0	37.0	438	382	12.8	1047	808	22.9	19.3	18.9	2.1	4.7	1.9	59.6	15.0	5.9	60.7
9/2-20....	19	246	26	90.1	55	34	38.2	433	433	....	991	816	17.7	19.6	18.1	6.1	3.5	1.7	51.4	13.0	4.3	65.6
9/21-28...	8	281	65	76.9	44	27	38.6	461	459	0.4	991	820	17.2	20.6	15.4	39.5	5.6	1.2	78.6	14.3	9.8	31.5
9/29-6....	8	279	215	22.9	50	30	40.0	474	476	....	963	881	8.5	22.8	20.7	9.2	3.7	2.4	35.2	12.3	15.6	....
10/7-16...	10	263	15	94.3	55	23	58.2	461	467	....	961	755	21.4	23.4	19.5	16.7	4.3	1.6	62.8	12.5	6.7	46.4
10/17-31..	15	297	28	90.6	61	23	62.2	475	472	0.7	1027	750	26.9	26.4	21.5	18.6	4.5	1.5	66.6	14.2	4.3	69.8
11/16-30..	15	178	50	72.0	32	25	21.8	358	364	....	977	865	11.5	10.8	12.3	....	1.7	1.0	41.2	10.5	5.5	47.6
12/1-7....	7	190	29	84.8	36	17	52.9	383	384	....	915	730	20.2	15.4	14.8	3.9	3.0	1.1	63.3	14.6	5.3	63.8
12/8-28...	21	204	17	91.5	40	14	65.0	379	376	0.8	913	740	18.9	16.4	13.9	15.2	3.5	1.5	57.1	11.8	4.2	64.4

TABULATION OF CHEMICAL DATA AND DAILY OPERATING CONDITIONS—MAY 3-13.

Date	Champaign Sewage		Air Used		Sludge by Vol. Per cent		Settleable Solids.	Turbidity			Oxygen Consumed			Alkalinity			Residue on Evap.		
May	Total Flow Gal.	Test Plant Feed	Cu. Ft. Gal.	Per cent to No. 1 Tank	Tank No. 1	Tank No. 2	Screened Sewage Per cent	Infl.	Effl.	Per cent Removal	Infl.	Effl.	Per cent Removal	Infl.	Effl.	Per cent Removal	Infl.	Effl.	Per cent Removal
3....	....	37,500	......	......	......	......	......	....	......	......	.....	......	......	....	......	......	......	......	....
4....	2,191,000	96,000	.715	60	......	......	.13	207	103	50.2	53	41	44.2	355	357	....	948	882	7.0
5....	2,207,000	88,800	.765	61	......	1	.14	177	98	44.8	58	31	46.6	355	355	....	957	847	11.5
6....	2,091,000	89,300	.760	61	1	4	.15	263	157	40.3	51	27	47.0	276	525	....	1012	......	....
7....	1,995,000	88,000	.770	60	......	6	.20	293	77	73.3	44	30	31.8	368	379	....	883	808	8.5
8....	1,898,000	89,700	.755	60	......	10	.16	283	63	77.5	50	34	31.9	363	371	....	925	813	12.1
9....	1,909,000	89,200	.760	60	3	12	.16	263	68	74.0	38	30	21.1	373	393	....	906	784	13.4
10....	1,764,000	81,300	.765	60	5	12	.23	172	32	81.3	52	25	51.8	394	395	....	980	812	17.2
11....	1,635,000	89,900	.745	61	8	13	.25	193	65	65.3	45	32	28.8	383	399	....	914	886	3.0
12....	1,560,000	86,800	.770	61	11	15	.30	213	79	62.8	58	34	41.3	395	416	....	912	760	16.6
13....	1,358,000	88,800	.755	60	15	15	.31	185	68	63.2	58	29	50.0	403	420	....	960	874	9.0
Ave..	1,860.800	88,800	.756	60.4	7.2	9.8	.20	225	81	63.9	50.7	31.3	38.2	367	401	(—9.4)	940	830	11.8

TABULATION OF CHEMICAL DATA AND DAILY OPERATING CONDITIONS—MAY 3-13—Continued.

Date.	Free Ammonia			Ammonia Albuminoid			Total Organic Nitrogen			Nitrates			Nitrites			Effluent Stability, Days	Influent Chlorides P. P. M.
May	Infl.	Effl.	Per cent Removal	Infl.	Effl.	Per cent Removal	Infl.	Effl.	Per cent Removal	Infl.	Effl.	Per cent Removal	Infl.	Effl.	Per cent Removal		
3............	......	......	....	......	......	......	......	......	....	......	......	....	......	......	....	......	.....
4............	10.7	10.2	4.7	4.5	3.8	15.6	11.2	7.2	35.6	4.1	3.2	21.9	.59	.56	2.0	......	68
5............	10.5	7.4	29.5	4.4	2.8	36.3	10.0	6.0	40.0	3.7	2.8	24.3	.59	.60	....	......	74
6............	15.1	71.0	....	2.3	2.5	......	8.8	8.0	9.1	2.3	2.1	8.7	.53	.54	....	......	67
7............	11.2	9.6	14.3	3.3	1.2	63.5	10.0	6.0	40.0	2.3	1.8	21.7	.56	.40	28.5	......	67
8............	10.6	11.1	....	3.2	1.2	62.5	8.0	2.8	65.0	4.3	1.5	65.0	.55	.47	14.5	......	69
9............	11.7	12.3	....	6.3	1.2	81.0	10.0	4.0	60.0	3.3	2.0	39.3	.52	.25	51.9	5	82
10............	15.2	11.3	25.7	3.9	1.2	69.2	11.2	2.8	75.0	1.9	1.0	47.3	.56	.26	53.4	7	101
11............	14.1	13.4	5.0	2.4	1.8	25.0	8.8	4.0	54.5	1.8	1.0	44.3	.28	.27	3.6	......	79
12............	12.0	15.2	....	4.1	2.3	43.8	8.0	4.0	50.0	2.8	1.1	60.1	.28	.16	42.8	10	77
13............	13.7	14.7	....	1.2	1.5	......	10.0	3.2	68.0	2.3	0.5	78.2	.28	.10	64.2	4	116
Ave..........	12.5	17.6	(—40.8)	3.6	1.9	47.3	9.6	4.8	50.0	2.9	1.6	44.8	.47	.36	23.4	6.5	88

Remarks: May 3rd, plant started up 10 P. M. May 12th to 13th, inclusive, air leak, No. 2 Tank.

TABULATION OF CHEMICAL DATA AND DAILY OPERATING CONDITIONS—MAY 14-21.

Date.	Champaign Sewage.		Air Used.		Per cent Sludge by Vol.		Solids. able Settle-	Turbidity.			Oxygen Consumed.			Alkalinity.			Residue on Evap.		
May	Total Flow Gal.	Test Plant Feed.	Cu. Ft. Gal.	Per cent to No. 1 Tank.	Tank No. 1.	Tank No. 2.	Screened Sewage, Per cent.	Infl.	Effl.	Per cent Removal.	Infl.	Effl.	Per cent Removal.	Infl.	Effl.	Per cent Removal.	Infl.	Effl.	Per cent Removal.
14....	1,430,000	85,3[illegible]0	.740	55	21	21	.39	253	72	71.5	64	30	53.1	399	418	....	988	752	23.8
15....	1,230,000	86,700	.755	50	26	18	.26	179	49	72.5	57	31	45.6	4[illegible]5	431	....	938	836	10.9
16....	1,307,000	87,700	.730	51	37	22	.36	237	73	60.0	63	35	44.4	423	445	....	1010	734	27.3
17....	1,277,000	85,100	.750	51	49	38	.34	307	45	85.2	68	31	47.3	421	431	....	1020	778	23.7
18....	1,284,00[illegible]	87,900	.740	51	62	51	.27	172	73	57.5	46	28	39.1	418	443	....	1000	863	13.7
19....	1,310,000	87,300	.740	51	65	53	.30	190	69	63.5	43	28	34.9	432	449	....	1004	800	20.3
20....	1,330,000	84,700	.760	51	63	56	.29	202	82	59.5	53	32	39.6	440	460	....	1[illegible]00	856	14.4
21....	1,260,000	89,100	.725	62	60	65	.31	225	89	60.5	53	34	35.8	438	461	....	1028	878	14.6
Ave..	1,304,000	86,700	.742	52.7	48	41	.31	221	69	68.8	56	31	44.4	422	442	(—4.8)	999	812	18.7

TABULATION OF CHEMICAL DATA AND DAILY OPERATING CONDITIONS—MAY 14-21—Continued.

Date.	Free Ammonia.			Albuminoid Ammonia.			Total Organic Nitrogen.			Nitrates.			Nitrites.				
May	Infl.	Effl.	Removal. Removal.	Infl.	Effl.	Per cent Removal.	Infl.	Effl.	Per cent Removal.	Infl.	Infl.	Per cent Removal.	Infl.	Effl.	Per cent Removal.	Influent Stability, Days.	Influent Chlorides, P. P. M.
14............	15.2	14.4	5.3	3.6	1.2	66.6	10.0	5.2	48.0	1.9	0.5	73.6	.45	.14	68.8	3	77
15............	16.8	17.6	....	4.8	1.3	72.8	8.0	6.0	25.0	3.3	0.2	93.8	.50	.04	92.0	2	72
16............	16.4	18.4	....	5.7	1.7	70.1	10.0	5.2	48.0	2.2	0.3	86.3	.42	.02	95.2	1	77
17............	17.4	15.9	8.6	6.0	1.5	75.0	7.2	4.0	44.4	2.9	0.2	93.0	.33	.02	93.8	1	99
18............	17.6	15.5	11.9	3.9	1.2	69.2	10.0	2.8	72.0	2.0	0.2	90.0	.25	.02	91.9	1	100
19............	17.6	15.8	10.2	2.5	1.5	40.0	10.0	2.8	72.0	2.0	0.2	90.0	.29	.17	41.3	3	110
20............	15.0	17.6	....	4.5	2.3	48.8	8.8	5.2	40.8	1.1	0.1	90.8	.16	.00	10[illegible].0	......	111
21............	19.8	18.3	7.6	4.0	2.0	50.0	10.0	5.2	48.0	1.3	0.1	92.2	.16	.00	100.0	......	120
Ave..........	17.0	16.7	1.8	4.4	1.6	63.6	9.2	4.5	51.2	2.1	0.2	89.5	.32	.05	84.3	1.8	96

TABULATION OF CHEMICAL DATA AND DAILY OPERATING CONDITIONS—MAY 22-JUNE 1.

Date.	Champaign Sewage.		Air Used.		Per cent Sludge by Vol.		Settle-able Solids.	Turbidity.			Oxygen Consumed.			Alkalinity.			Residue on Evap.		
May	Total Flow Gal.	Test Plant Feed.	Cu. Ft. Gal.	Per cent to No. 1 Tank.	Tank No. 1.	Tank No. 2.	Screened Sewage.	Infl.	Effl.	Per cent Removal.	Infl.	Effl.	Per cent Removal.	Infl.	Effl.	Per cent Removal.	Infl.	Effl.	Per cent Removal.
22.....	1,043,000	87,800	.660	67	......	......	.31	229	133	41.9	57	40	29.8	440	466	....	1106	1036	6.3
23.....	1,164,000	....	......	57	37	61	.33	163	......	......	......	......	......	......	......	....	......	......	....
24.....	1,468,000	....	......	52	79	86	.32	182	......	......	......	......	......	......	......	....	......	......	....
25.....	2,150,000	89,000	.740	60	90	77	.41	337	75.	77.6	55	31	25.4	296	399	....	1080	775	28.2
26.....	2,544,000	88,700	.745	60	70	72	.14	173	25	85.6	32	30	6.7	237	262	....	948	821	13.4
27.....	2,453,000	88,700	.740	60	73	82	.16	162	17	89.5	30	30	0.0	285	304	....	918	823	10.4
28.....	2,185,000	87,700	.740	65	63	62	.18	180	29	83.8	43	29	32.6	327	345	....	933	832	....
29.....	2,082,000	89,200	.725	65	59	33	.22	170	35	79.5	42	23	45.2	323	362	....	1000	922	7.8
30.....	2,117,000	89,500	.735	64	55	33	.14	180	25	86.0	36	23	36.2	349	368	....	908	823	9.3
31.....	2,130,000	89,200	.735	65	70	32	.22	190	20	89.5	43	25	41.8	365	388	....	886	747	15.7
June 1.	2,131,000	87,100	.735	64	69	60	.23	220	19	91.2	40	26	35.0	372	393	....	882	772	12.4
Ave...	1,951,000	88,500	.730	61.7	66.5	59.8	.24	199	42	78.9	42	28.6	31.9	333	365	(—9.8)	962	856	11.1

TABULATION OF CHEMICAL DATA AND DAILY OPERATING CONDITIONS—MAY 22-JUNE 1—Continued.

Date.	Free Ammonia.			Albuminoid Ammonia.			Total Organic Nitrogen.			Nitrates.			Nitrites.			Influent Stability, Days.	Influent Chlorides, P. P. M.
May	Infl.	Effl.	Per cent Removal.	Infl.	Effl.	Per cent Removal.	Infl.	Effl.	Per cent Removal.	Infl.	Effl.	Per cent Removal.	Infl.	Effl.	Per cent Removal.		
22...........	18.5	20.0	....	3.9	2.4	38.4	12.0	12.0	....	1.7	0.1	94.1	0.16	0.0	100.0	......	142
23...........	......	......	....	......	......	......	......	......	....	......	......	......	......	......	......	......	......
24...........	......	......	....	......	......	......	......	......	....	......	......	......	......	......	......	......	......
25...........	13.1	11.6	11.4	2.3	3.2	......	10.0	5.2	48.0	4.9	0.7	85.4	0.16	0.01	93.8	......	83
26...........	5.3	3.8	28.3	1.4	0.9	35.7	4.0	2.8	30.0	14.6	9.3	36.3	0.56	1.55	....	3	69
27...........	7.2	6.4	11.2	1.7	1.2	29.4	4.0	2.8	30.0	10.0	10.7	....	1.10	2.30	....	4	80
28...........	7.2	9.4	....	0.9	0.5	44.3	5.6	4.0	28.6	7.3	6.2	15.3	1.10	1.70	....	10	77
29...........	7.6	9.6	....	1.9	0.7	63.1	6.0	2.8	53.3	8.0	4.7	41.3	1.80	0.82	55.6	3	76
30...........	7.8	9.6	....	1.2	0.4	66.8	6.0	2.8	53.3	4.3	1.6	62.8	1.17	0.93	25.0	10	80
31...........	7.8	10.0	....	2.3	1.2	47.8	8.0	4.0	50.0	2.7	1.0	62.9	0.36	0.11	69.3	6	77
June 1........	8.9	9.8	....	2.5	0.9	63.9	8.0	2.8	65.0	4.0	1.0	75.0	0.32	0.03	90.5	2	79
Ave...........	9.3	10.0	(—8.1)	2.0	1.3	36.8	7.1	4.4	38.3	6.4	3.9	38.8	0.82	0.76	7.3	5.4	85

Remarks: May 22, trouble with blower; May 23 and 24, Tank No 2 Septic—aerated 24 hours without feed.

TABULATION OF CHEMICAL DATA AND DAILY OPERATING CONDITIONS—JUNE 2-15.

Date.	Champaign Sewage.		Air Used.		Per cent Sludge by Vol.		Settleable Solids.	Turbidity.			Oxygen Consumed.			Alkalinity.			Residue on Evap.		
June	Total Flow Gal.	Test Plant Feed.	Cu. Ft. Gal.	Per cent to No. 1 Tank.	Tank No. 1.	Tank No. 2.	Screened Sewage.	Infl.	Effl.	Per cent Removal.	Infl.	Effl.	Per cent Removal.	Infl.	Effl.	Per cent Removal.	Infl.	Effl.	Removal. Per cent
2	2,056,000	93,800	.700	64	65	66	.22	163	9	94.4	49	24	51.0	381	386	....	990	772	22.1
3	1,900,000	96,000	.690	64	60	67	.19	183	12	93.3	51	28	45.2	387	391	....	860	857	0.4
4	1,778,000	94,600	.700	63	56	66	.21	180	13	92.8	48	29	39.6	386	397	....	978	826	15.5
5	1,630,000	94,400	.710	63	51	68	.18	170	23	86.2	57	29	49.2	380	395	....	964	792	17.8
6	1,660,000	96,300	.680	63	49	57	.34	189	62	67.2	60	37	38.3	367	410	....	1013	1018	....
7	1,580,000	95,600	.670	62	41	59	.23	180	32	82.0	57	28	50.8	397	412	....	884	776	12.1
8	1,392,000	91,500	.690	62	37	54	.23	152	53	65.2	45	29	35.6	399	412	....	1036	805	22.3
9	1,370,000	96,400	.670	61	41	61	.27	222	23	89.6	49	29	40.7	391	406	....	929	773	16.8
10	1,290,000	94,200	.680	61	39	69	.23	173	39	77.5	55	31	43.7	411	415	....	1000	764	23.6
11	1,282,000	92,800	.700	61	41	67	.31	250	43	82.5	46	27	41.3	398	398	....	967	727	24.9
12	1,103,000	94,000	.690	62	34	59	.16	180	29	83.8	53	25	52.8	405	416	....	912	776	14.9
13	1,122,000	92,200	.700	61	29	48	.26	239	53	77.9	55	33	40.0	431	449	....	1094	935	14.6
14	1,136,000	62,300	1.040	63	25	50	.19	263	77	70.6	67	39	41.8	432	407	5.8	1019	973	4.5
15	1,145,000	86,000	.730	64	30	49	.26	267	73	72.8	67	33	50.7	443	449	....	1001	852	14.8
Ave.	1,460,000	93,600	.720	62.4	43	60	.23	201	38	80.5	54	30	44.5	401	410	(—2.4)	903	817	9.5

TABULATION OF CHEMICAL DATA AND DAILY OPERATING CONDITIONS—JUNE 2-15—Continued.

Date.	Free Ammonia.			Albuminoid Ammonia.			Total Organic Nitrogen.			Nitrates.			Nitrites.				
June	Infl.	Effl.	Per cent Removal.	Infl.	Effl.	Per cent Removal.	Infl.	Effl.	Per cent Removal.	Infl.	Effl.	Per cent Removal.	Infl.	Effl.	Per cent Removal.	Effluent Stability, Days.	Influent Chlorides, P. P. M.
2	7.6	9.6	....	1.5	0.7	53.2	10.0	2.8	72.0	3.6	0.4	88.9	0.20	0.02	90.0	5	127
3	8.6	9.7	....	2.9	1.6	44.8	8.8	2.8	68.2	4.0	0.2	94.8	0.44	0.02	95.4	10	89
4	11.1	10.7	3.6	2.3	1.6	30.4	7.2	2.8	61.1	2.1	0.2	90.3	0.39	0.13	66.7	10	82
5	11.8	10.2	13.6	3.7	1.3	64.8	10.0	5.2	48.0	2.8	0.4	85.6	0.30	0.11	63.3	......	79
6	9.3	10.7	....	1.8	2.5	......	12.0	12.0	....	1.5	0.2	86.7	0.23	0.06	73.8	5	97
7	10.6	9.4	11.3	2.4	1.1	54.2	10.0	4.0	60.0	2.5	0.1	95.8	0.23	0.02	91.2	4	81
8	12.1	8.6	28.8	4.3	1.5	64.9	10.0	5.2	48.0	2.2	0.1	95.4	0.23	0.00	100.0	6	135
9	11.3	9.8	13.2	5.3	1.1	79.2	9.6	5.2	45.8	2.9	0.2	93.1	0.17	0.00	100.0	3	103
10	13.7	9.6	29.8	4.7	2.0	57.3	10.0	5.2	48.0	1.6	0.3	81.2	0.17	0.00	100.0	4	160
11	15.6	8.7	44.2	5.2	1.7	67.3	12.0	20.0	....	1.3	0.4	69.2	0.10	0.00	100.0	3	97
12	14.2	12.2	14.1	3.9	1.2	69.1	14.0	18.0	....	1.9	0.1	94.8	0.13	0.00	100.0	......	98
13	14.2	11.3	20.4	4.4	2.3	47.7	10.0	6.0	40.0	1.3	0.2	84.6	0.11	0.00	100.0	3	185
14	15.6	7.8	50.0	5.3	2.0	62.2	10.0	8.0	20.0	1.3	0.1	92.1	0.13	0.00	100.0	1	109
15	17.0	12.5	26.4	6.0	1.3	78.3	14.0	6.0	57.1	1.5	0.1	93.1	0.11	0.01	90.9	3	117
Ave.	12.3	10.0	18.7	3.8	1.6	59.0	11.1	6.8	38.7	2.2	0.2	90.9	0.20	0.03	85.0	4.8	111

Remarks: June 3, 4, 5, 6 and 14, air leak, No. 2 Tank.

TABULATION OF CHEMICAL DATA AND DAILY OPERATING CONDITIONS—JUNE 16-30.

Date.	Champaign Sewage.		Air Used.		Per cent Sludge by Vol.		Settle-able Solids.	Turbidity.			Oxygen Consumed.			Alkalinity.			Residue on Evap.		
June	Total Flow Gal.	Test Plant Feed, Gal.	Cu. Ft. Gal.	Per cent to No. 1 Tank.	Tank No. 1.	Tank No. 2.	Screened Sewage, Per cent.	Infl.	Effl.	Per cent Removal.	Infl.	Effl.	Per cent Removal.	Infl.	Effl.	Per cent Removal.	Infl.	Effl.	Per cent Removal.
16.....	1,219,000	96.700	.660	64	32	48	.24	237	67	71.8	72	37	48.4	453	444	1.9	988	875	11.4
17.....	1,040,000	87,500	.720	68	30	51	.30	259	67	74.1	59	29	50.8	435	443	....	998	860	13.8
18.....	1,002,000	89,200	.710	66	22	39	.28	263	87	66.9	46	33	28.2	431	430	0.2	910	952	....
19.....	900,000	88,100	.730	64	23	29	.20	267	110	58.8	68	36	47.1	435	435	0.0	882	990	....
20.....	1,182,000	87.200	.730	64	22	33	.39	297	133	55.2	66	47	28.8	441	450	....	978	940	3.9
21.....	1,057,000	85,500	.750	66	23	36	.25	277	113	59.1	65	55	15.4	457	437	4.5	840	900	....
22.....	1,044,000	87,000	.730	64	24	36	.29	303	153	49.4	81	54	33.4	461	462	....	1127	2075	....
23.....	1,045,000	84,700	.750	63	25	20	.47	223	103	53.7	62	40	35.5	444	460	....	978	900	8.0
24.....	994,000	88.700	.720	63	21	37	.23	230	140	39.2	55	39	29.1	467	463	0.9	968	964	0.4
25.....	945,000	85,900	.740	64	23	36	.45	253	126	50.1	69	43	37.7	431	456	....	1058	950	10.2
26.....	802,000	84,500	.750	63	25	36	.28	257	107	58.2	68	45	33.8	440	451	....	976	960	1.6
27.....	959,000	87,000	.730	64	27	36	.31	287	123	56.9	71	40	43.7	453	453	0.0	1068	960	10.0
28.....	990,000	86,900	.730	64	32	38	.20	267	75	71.8	59	40	32.2	435	420	3.4	1068	788	28.0
29.....	925,000	88,200	.720	60	30	35	.28	187	160	14.4	53	41	22.6	451	448	0.8	978	1050	....
30.....	850,000	87.400	.730	61	24	41	.24	129	147	......	83	73	12.4	471	451	4.2	1052	999	5.0
Ave...	997,000	87,600	.726	64	25.6	36	.39	249	114	54.2	65	43.5	30.1	443	442	0.3	991.3	1011	(—1.9)

TABULATION OF CHEMICAL DATA AND DAILY OPERATING CONDITIONS—JUNE 16-30—Continued.

Date.	Free Ammonia.			Albuminoid Ammonia.			Total Organic Nitrogen.			Nitrites.			Nitrates.			Effluent Stability, Days.	Influent Chlorides, P. P. M.
June	Infl.	Effl.	Per cent Removal.	Infl.	Effl.	Per cent Removal.	Infl.	Effl.	Per cent Removal.	Infl.	Effl.	Per cent Removal.	Effl.	Effl.	Per cent Removal.		
16	15.5	10.3	33.6	4.5	2.2	51.2	12.0	8.0	33.3	1.2	0.2	83.2	.08	0.0	100	......	112
17	14.5	10.6	26.9	6.0	2.4	60.0	12.8	10.0	21.8	1.2	0.2	83.2	.07	0.0	100	......	112
18	15.8	10.8	31.6	2.9	2.4	17.3	11.2	8.0	28.6	0.9	0.1	88.9	.08	0.0	100	......	115
19	15.9	10.8	32.1	5.6	3.0	46.3	12.0	10.0	16.7	1.2	0.1	91.6	.07	0.0	100	......	117
20	15.8	13.5	14.5	5.3	4.3	18.8	14.0	12.0	14.3	1.1	0.2	81.9	.09	0.0	100	......	114
21	15.8	10.1	36.1	2.9	2.5	13.8	8.0	11.2	....	0.7	0.1	85.8	.09	0.0	100	......	123
22	16.9	12.8	24.2	6.5	4.1	36.8	18.0	18.0	0.0	1.1	0.3	72.8	.01	0.0	100	......	121
23	17.6	14.1	19.9	4.4	3.3	25.0	10.0	10.0	0.0	0.9	0.1	88.9	.09	0.0	100	......	127
24	15.5	13.1	15.4	4.4	4.1	6.8	10.0	12.0	....	0.9	0.1	88.9	.06	0.0	100	......	123
25	17.5	15.0	14.3	3.3	3.7	......	13.0	16.0	....	0.6	0.3	50.0	.09	0.9	100	......	118
26	20.2	15.6	22.7	4.8	3.9	18.8	12.0	16.0	....	1.0	0.3	70.0	.05	0.0	100	......	129
27	19.4	16.2	16.5	3.7	3.4	8.1	17.0	20.0	....	0.6	0.4	33.3	.09	0.0	100	......	110
28	16.7	11.0	34.2	4.4	3.2	27.2	13.0	9.0	30.8	1.3	0.1	92.2	.07	0.0	100	......	115
29	18.6	15.7	15.6	3.3	4.7	......	10.0	22.0	....	0.8	0.2	75.0	.06	0.0	100	......	113
30	19.9	15.4	22.7	3.6	3.5	2.8	14.0	14.0	0.0	1.4	0.3	78.7	.06	0.0	100	......	124
Ave.	17.0	12.9	23.2	4.4	3.4	22.7	12.5	13.1	(—4.8)	1.0	0.2	80.0	.07	0.0	100	......	118

Remarks: June 16 to July 10, inclusive—Sludge allowed to overflow with effluent

TABULATION OF CHEMICAL DATA AND DAILY OPERATING CONDITIONS—JULY 1-10.

Date.	Champaign Sewage.		Air Used.		Per cent Sludge by Vol.		Settle-able Solids.	Turbidity.			Oxygen Consumed.			Alkalinity.			Residue on Evap.		
July	Total Flow Gal.	Total Flow Feed, Gal.	Cu. Ft. Gal.	Per cent to No. 1 Tank.	Tank No. 1.	Tank No. 2.	Screened Sewage, Per cent.	Infl.	Effl.	Per cent Removal.	Infl.	Effl.	Per cent Removal.	Infl.	Effl.	Per cent Removal.	Infl.	Effl.	Per cent Removal.
1.....	886,000	84,000	.860	61	19	38	.27	170	123	27.6	64	40	37.4	470	457	2.8	965	945	2.1
2.....	956,000	85,700	.840	61	25	38	.30	310	92	70.6	63	42	33.3	431	446	....	928	856	7.7
3.....	757,000	86,200	.830	61	25.5	34	.22	307	123	60.0	70	52	25.8	454	449	1.1	1099	1004	8.7
4.....	752,000	88,600	.810	61	22	37.5	.23	207	179	13.6	64	49	23.3	444	451	....	985	1020	....
5.....	857,000	66,700	.820	59	22.5	42.5	.27	280	150	46.3	70	37	47.1	502	460	8.3	1183	1009	14.9
6....	1,195,000	85,100	.870	60	21.5	46	.26	233	174	25.3	.....	52	......	....	450	....	910	1020	......
7.....	976,000	87,700	.830	62	17	38.5	.25	217	120	44.7	49	37	24.4	383	432	....	985	950	3.6
8.....	1,046,000	88,900	.830	60	20.5	39.5	.20	183	98	46.4	50	41	18.0	440	420	4.6	924	897	2.9
9....	867,000	86,400	.850	61	26	45	.13	163	183	......	62	67	......	453	444	1.9	880	1050	......
10.....	755,000	88,700	.830	62	19	45.5	.25	240	189	21.2	67	48	28.3	461	467	....	998	1036	......
Ave...	904.700	84,800	.840	61	21.8	40.5	.24	231	143	38.1	62	46.5	25.1	449	448	0.2	986	979	0.8

TABULATION OF CHEMICAL DATA AND DAILY OPERATING CONDITIONS—JULY 1-10—Continued.

Date.	Free Ammonia.			Albuminoid Ammonia.			Total Organic Nitrogen.			Nitrates.			Nitrites.				
July	Infl.	Effl.	Per cent Removal.	Infl.	Effl.	Per cent Removal.	Infl.	Effl.	Per cent Removal	Infl.	Effl.	Per cent Removal.	Infl.	Effl.	Per cent Removal.	Effluent Stability, Days.	Influent Chlorides, Influent
1............	18.0	14.7	18.3	4.4	3.2	27.2	16	18	....	0.6	0.4	33.3	.06	0.0	100	......	129
2............	15.1	14.1	7.3	4.4	2.9	34.1	14	10	28.5	0.5	0.1	80.0	.06	0.0	100	......	127
3............	16.9	14.6	13.6	6.5	3.4	47.7	18	17	5.6	0.8	0.3	62.2	.05	0.0	100	......	187
4............	19.4	14.7	24.2	4.7	4.7	0.0	14	24	....	0.6	0.2	66.6	.06	0.0	100	......	138
5............	17.0	12.1	28.8	5.2	3.8	26.9	14	14	0.0	0.7	0.1	85.7	.03	0.0	100	......	146
6............	......	11.0	....	......	4.4	......	10	16	....	1.0	0.4	60.0	......	0.0	....	......	......
7............	14.0	10.0	28.6	2.9	4.7	......	10	10	0.0	0.7	0.2	71.4	.06	0.1	83.3	......	115
8............	12.9	10.0	22.5	3.1	3.1	0.0	8	12	....	0.4	0.7	....	.08	0.0	100	......	121
9............	16.5	14.6	11.2	4.9	7.4	......	12	20	....	0.3	0.2	33.3	.02	0.0	100	......	128
10............	19.0	16.4	4.7	4.7	5.7	......	18	20	....	0.4	0.1	75.0	.03	0.0	100	......	128
Ave...........	16.5	13.4	18.8	4.5	4.3	4.4	13.4	16.1	(—20.1)	0.6	0.3	55.0	.05	0.0	98.2	......	101.3

Remarks: July 10—Rakes catching on tray—shut down for repairs.

TABULATION OF CHEMICAL DATA AND DAILY OPERATING CONDITIONS—JULY 15-31.

Date.	Champaign Sewage.		Air Used.		Per cent Sludge by Vol.		Settle-able Solids.	Turbidity.			Oxygen Consumed.			Alkalinity.			Residue on Evap.		
July	Total Flow Gal.	Test Plant Feed, Gal.	Cu. Ft. Gal.	Per cent to No. 1 Tank.	Tank No. 1.	Tank No. 2.	Screened Sewage, Per cent.	Infl.	Effl.	Per cent Removal.	Infl.	Effl.	Per cent Removal.	Infl.	Effl.	Per cent Removal.	Infl.	Effl.	Per cent Removal.
15.....	790,000	67,300	.980	62	11	......	.21	229	103	55.1	58	40	31.0	435	469	....	1004	948	5.4
16.....	844,000	86,700	.830	59	24	15.5	.10	217	43	80.0	52	29	44.3	453	420	7.3	925	782	15.5
17.....	761,000	86,800	.820	60	36.5	30	.09	180	103	42.8	49	39	20.4	435	455	....	893	847	5.1
18.....	1,152,000	88,400	.770	60	34	50	.32	300	86	71.2	57	40	29.8	399	436	....	1054	897	15.7
19.....	852,000	88,600	.790	59	42	56	.24	253	167	34.1	59	45	23.7	468	430	8.1	990	913	7.8
20.....	814,000	87,000	.790	60	40	56	.19	219	120	45.2	57	42	26.3	463	461	0.4	956	951	0.4
21.....	818,000	85,800	.810	60	38	55	.10	233	105	55.0	50	43	14.0	449	465	....	937	920	1.8
22.....	818,000	87,800	.800	60	42	53.5	.20	270	57	41.8	59	42	18.8	453	454	....	947	830	12.4
23.....	818,000	83,700	.750	62	48	57.5	.18	233	74	68.2	68	38	44.1	434	161	63.0	960	752	21.8
24.....	685,000	89,500	.670	61	43.5	67.5	.14	270	143	47.0	56	43	23.2	432	147	66.0	920	852	7.4
25.....	841,000	72,500	.900	61	37	53.5	.23	233	120	48.4	53	29	45.2	419	297	29.1	1003	868	13.5
26.....	833,000	48,600	1.350	61	43	55	.19	230	19	92.0	52	27	48.1	457	307	32.8	991	759	23.4
27.....	1,140,000	64,600	1.020	59	39.5	36.5	.20	245	103	57.9	68	43	36.8	443	449	....	1068	904	15.4
28.....	1,100,000	74,800	.880	61	45	39	.25	303	107	64.6	51	48	5.9	409	436	....	1037	866	16.5
29.....	943,000	74,400	.880	58	45	42	.25	199	46	76.8	44	26	41.0	397	254	36.0	936	744	20.5
30.....	880,000	76,100	.850	59	46	53.5	.33	243	62	74.2	64	21	51.5	428	384	18.0	881	805	8.6
31.....	711,000	74,400	.880	59	47	63	.40	255	47	81.7	59	38	35.6	455	367	19.4	893	753	15.6
Ave...	876,000	78,600	.870	60	39	49	.21	242	88.5	63.4	56	37	33.4	437	374	14.4	964	846	12.2

TABULATION OF CHEMICAL DATA AND DAILY OPERATING CONDITIONS—JULY 15-31—Continued.

Date.	Free Ammonia.			Albuminoid Ammonia.			Total Organic Nitrogen.			Nitrates.			Nitrites.			Effluent Stability, Days.	Influent Chlorides, P. P. M.
July	Infl.	Effl.	Per cent Removal.	Infl.	Effl.	Per cent Removal.	Infl.	Effl.	Per cent Removal.	Infl.	Effl.	Per cent Removal.	Infl.	Effl.	Per cent Removal.		
15	22.9	18.6	18.8	4.0	3.1	22.5	8.0	10.0	....	0.4	0.2	50.0	.03	.02	33.3	......	95
16	18.0	16.3	9.4	4.4	2.3	25.0	12.0	5.2	56.8	0.2	0.1	50.0	.01	0.0	100.0	......	85
17	24.6	16.0	35.0	4.4	4.0	9.1	10.0	8.0	20.0	0.4	0.2	50.0	.03	0.0	100.0	......	103
18	14.6	14.7	....	3.1	4.0	......	12.0	12.0	0.0	1.2	0.1	91.5	.13	0.0	100.0	......	120
19	19.3	14.3	26.0	3.3	2.7	18.2	10.0	4.0	60.0	0.7	0.1	85.7	.03	0.01	66.7	......	118
20	20.6	18.0	12.6	3.3	3.4	......	4.0	12.0	....	0.3	0.2	33.3	.01	0.0	100.0	......	131
21	20.6	14.6	29.1	2.9	1.7	41.3	10.0	12.0	....	0.6	0.0	100.0	.04	0.0	100.0	......	111
22	18.6	18.0	3.2	3.3	1.2	63.7	8.0	10.0	....	0.5	0.1	80.0	.04	0.0	100.0	......	121
23	22.5	19.0	15.6	3.1	2.4	22.6	12.0	8.0	33.3	0.6	0.2	66.6	.02	0.0	100.0	......	69
24	22.2	19.3	13.6	3.6	3.5	2.9	2.8	16.0	....	0.4	0.2	50.0	.03	0.0	100.0	......	113
25	20.4	17.0	16.7	3.3	2.9	12.1	14.0	14.0	0.0	0.8	0.1	87.5	.03	0.0	100.0	......	122
26	16.3	16.0	1.9	3.3	1.3	60.5	4.0	12.0	....	0.3	0.1	66.6	.06	0.0	100.0	......	145
27	23.6	17.3	26.7	4.9	3.3	32.6	14.0	12.0	14.3	0.2	0.1	50.0	.03	0.0	100.0	......	117
28	17.3	16.6	4.1	3.6	2.5	30.6	12.0	8.0	33.4	1.0	0.1	90.0	.08	0.0	100.0	......	131
29	18.0	15.6	13.3	2.8	1.7	39.3	8.0	6.0	25.0	0.5	0.1	80.0	.04	0.0	100.0	1	121
30	18.6	16.2	12.9	4.0	1.6	60.0	10.0	8.0	20.0	0.1	0.1	0.0	.01	0.0	100.0	1	99
31	22.0	17.3	21.3	3.6	1.9	47.3	10.0	6.0	40.0	0.1	0.1	0.0	.02	0.0	100.0	1	107
Ave.	20.0	16.7	16.5	3.6	2.5	30.6	9.5	9.6	(—1.0)	0.5	.12	75.7	.04	.002	95.0	1	112

Remarks: July 15 to 81, inclusive—Sludge very light and overflowed in spite of drawing 88.000 gallons during run.

TABULATION OF CHEMICAL DATA AND DAILY OPERATING CONDITIONS—AUG. 1-15.

Date.	Champaign Sewage.		Air Used.		Per cent Sludge by Vol.		Settleable Solids.	Turbidity.			Oxygen Consumed.			Alkalinity.			Residue on Evap.		
Aug.	Total Flow Gal.	Test Plant Feed, Gal.	Cu. Ft. Gal.	Per cent to No. 1 Tank.	Tank No. 1.	Tank No. 2.	Screened Sewage, Per cent.	Infl.	Effl.	Per cent Removal.	Infl.	Effl.	Per cent Removal.	Infl.	Effl.	Per cent Removal.	Infl.	Effl.	Per cent Removal.
1.....	972,000	68,500	.940	60	53	56	.36	253	68	73.0	93	42	54.8	411	296	27.9	1061	860	18.9
2.....	1,050,000	74,700	.810	62	69	79	.24	229	37	83.8	54	23	38.8	404	303	25.0	988	678	31.3
3.....	899,000	76,300	.810	64	71	38	.27	227	33	85.5	50	38	24.0	347	358	....	922	858	6.9
4.....	779,000	74,800	.820	64	68	61	.28	217	35	83.8	75	36	52.0	451	351	22.2	1005	788	21.6
5.....	740,000	70,000	.810	64	62	77	.27	227	35	75.8	59	27	54.2	451	367	18.6	868	853	1.7
6.....	824,000	70,000	.830	67	51	58	.28	192	37	80.5	54	27	50.0	433	451	....	946	783	17.3
7.....	680,000	70,200	.840	64	60	77	.23	242	42	82.8	50	29	42.0	469	448	4.5	996	854	14.3
8.....	813,000	68,400	.850	64	43	59	.34	262	72	72.6	84	37	55.9	462	469	....	1116	976	13.1
9.....	843,000	55,000	.870	65	44	65	.32	263	143	45.6	56	43	23.2	425	458	....	1074	920	14.3
10.....	941,000	75,100	.980	64	48	77	.33	283	88	68.8	82	40	51.2	401	439	....	1050	858	18.2
11.....	1,377,000	71,200	.790	65	43	67	.30	249	17	93.2	74	34	54.1	323	207	35.9	904	636	29.6
12.....	1,002,000	70,200	.830	64	41	37	.20	222	25	88.8	79	34	56.9	429	421	1.9	1040	766	26.3
13.....	1,076,000	71,700	.840	64	62	33	.29	302	28	90.3	73	36	50.6	399	431	....	1096	809	26.3
14.....	738,000	74,200	.850	63	80	88	.28	253	47	81.3	84	37	56.0	448	428	4.5	1108	847	23.6
15.....	879,000	70,300	.850	65	75	71	.26	232	26	88.9	67	35	47.8	477	363	2.4	1150	878	23.6
Ave...	907,000	70,700	.850	64	58	65	.28	243	50	79.3	69	35	49.3	422	386	8.5	1021	824	19.3

TABULATION OF CHEMICAL DATA AND DAILY OPERATING CONDITIONS—AUG. 1-15—Continued.

Date.	Free Ammonia.			Albuminoid Ammonia.			Total Organic Nitrogen.			Nitrates.			Nitrites.				
Aug.	Infl.	Effl.	Per cent Removal.	Infl.	Effl.	Per cent Removal.	Infl.	Effl.	Per cent Removal.	Infl.	Effl.	Per cent Removal.	Infl.	Effl.	Per cent Removal.	Effluent Stability, Days.	Influent Chlorides, P. P. M.
1...........	17.0	18.0	....	7.2	3.3	54.1	18.0	10.0	44.5	0.8	0.1	87.5	.05	0.0	100.0	1.5	143
2...........	16.5	13.7	17.0	4.0	1.6	60.0	14.0	6.0	57.0	0.7	0.1	85.7	.14	0.0	100.0	2.0	89
3...........	20.0	16.5	17.5	4.0	2.4	40.0	10.0	10.0	0.0	0.7	0.1	85.7	.06	0.0	100.0	2.0	107
4...........	20.0	16.5	17.5	7.3	1.6	78.0	14.0	6.0	57.0	0.8	0.1	87.5	.05	0.0	100.0	1.5	125
5...........	18.3	13.8	24.6	4.0	2.0	50.0	12.0	6.0	50.0	0.2	0.0	100.0	.03	0.0	100.0	1.0	106
6...........	19.5	15.2	22.1	4.1	2.1	48.7	12.0	6.0	50.0	0.2	0.0	100.0	.04	0.0	100.0	1.0	107
7...........	24.6	18.6	24.4	4.7	2.5	46.8	16.0	10.0	37.5	0.3	0.0	100.0	.03	0.0	100.0	1.0	123
8...........	19.3	17.6	8.8	5.9	4.0	32.2	14.0	12.0	14.3	0.5	0.1	80.0	.03	0.0	100.0	1.0	142
9...........	19.5	16.0	18.0	4.7	3.5	25.5	10.0	10.0	0.0	0.4	0.0	100.0	.04	0.0	100.0	0.5	157
10...........	16.3	12.4	23.9	8.4	3.5	58.8	16.0	14.0	12.5	0.8	0.4	50.0	.09	0.0	100.0	1.5	85
11...........	14.7	7.7	47.7	3.5	1.7	51.5	10.0	5.2	48.0	2.1	0.1	95.2	.24	0.0	100.0	3.0	84
12...........	18.0	16.5	8.3	4.7	1.6	65.9	12.0	4.0	66.6	0.8	0.7	12.5	.03	0.1	66.7	8.0	113
13...........	18.3	15.2	16.9	5.9	1.7	71.2	16.0	4.0	75.0	1.1	0.1	91.0	.04	0.0	100.0	3.0	95
14...........	20.4	15.0	26.5	6.0	1.9	68.3	16.0	5.2	67.4	1.3	0.2	84.5	.03	0.0	100.0	1.5	125
15...........	18.6	17.1	8.1	4.0	2.0	50.0	10.0	5.2	48.0	1.0	0.3	70.0	.02	0.0	100.0	1.0	167
Ave...........	18.7	15.3	18.2	5.2	2.3	55.8	13.7	7.6	44.5	0.8	0.2	75.0	.06	0.0	97.8	2.0	118

TABULATION OF CHEMICAL DATA AND DAILY OPERATING CONDITIONS—AUG. 16-21.

Date.	Champaign Sewage.		Air Used.		Per cent Sludge by Vol.		Settleable Solids.	Turbidity.			Oxygen Consumed.			Alkalinity.			Residue on Evap.		
Aug.	Total Flow Gal.	Test Plant Feed, Gal.	Cu. Ft. Gal.	Per cent to No. 1 Tank.	Tank No. 1.	Tank No. 2.	Screened Sewage, Per cent.	Infl.	Effl.	Per cent Removal.	Infl.	Effl.	Per cent Removal.	Infl.	Effl.	Per cent Removal.	Infl.	Effl.	Per cent Removal.
16.....	790,000	55,000	1.10	63	86	71	.27	233	22	90.0	103	50	51.3	492	457	7.1	1158	868	25.1
17.....	825,000	67,000	.91	64	80	83	.26	290	29	89.8	79	40	49.3	478	475	0.7	1101	853	22.5
18.....	698,000	55,300	1.10	66	75	72	.46	339	45	86.6	94	43	54.2	455	365	19.8	1560	830	46.7
19.....	739,000	58,300	1.05	64	82	65	.32	270	25	90.5	80	41	48.8	470	336	28.5	1028	782	23.9
20.....	728,000	66,000	.93	63	68	60	.32	200	43	78.5	68	27	60.5	439	352	19.8	1004	801	20.1
21.....	622,000	68,800	.92	64	83	61	.16	240	37	84.8	78	47	39.7	443	415	6.3	1120	950	15.2
Ave...	734,000	62,000	1.00	64	79	69	.29	262	33	87.4	84	41	51.2	463	400	13.6	1162	847	27.1

TABULATION OF CHEMICAL DATA AND DAILY OPERATING CONDITIONS—AUG. 16-21—Continued.

Date.	Free Ammonia.			Albuminoid Ammonia.			Total Organic Nitrogen.			Nitrates.			Nitrites.			Effluent Stability, Days.	Influent Chlorides, P. P. M.
Aug.	Infl.	Effl.	Per cent Removal.	Infl.	Effl.	Per cent Removal.	Infl.	Effl.	Per cent Removal.	Infl.	Effl.	Per cent Removal.	Infl.	Effl.	Per cent Removal.		
16............	24.0	17.8	25.8	5.7	2.0	64.8	40.0	4.0	90.0	0.7	0.1	85.7	.01	0.0	100.0	1.0	172
17............	19.6	18.3	6.6	6.4	1.6	75.0	18.0	5.2	71.0	0.6	0.1	83.3	.03	0.0	100.0	1.0	125
18............	20.3	18.3	10.4	8.5	2.0	76.5	22.0	6.0	72.8	0.9	0.1	86.7	.04	0.0	100.0	1.0	95
19............	21.0	16.0	23.8	5.2	2.0	61.5	18.0	5.2	71.2	0.9	0.1	86.7	0.0	0.0	100.0	1.5	142
20............	19.3	10.0	48.3	4.1	1.7	58.6	16.0	4.2	73.6	0.7	0.1	85.7	.01	0.0	100.0	2.0	117
21............	22.2	22.5	....	5.9	2.3	61.0	16.0	12.0	25.0	1.1	0.1	90.9	.02	0.0	100.0	0.5	103
Ave...........	21.0	17.1	18.6	5.9	1.9	67.8	21.6	6.1	71.8	0.8	0.1	87.5	.02	0.0	100.0	1.2	126

TABULATION OF CHEMICAL DATA AND DAILY OPERATING CONDITIONS—AUG. 22-SEPT. 1.

Date.	Champaign Sewage.		Air Used.		Per cent Sludge by Vol.		Settle-Able Solids.	Turbidity.			Oxygen Consumed.			Alkalinity.			Residue on Evap.		
Aug.	Total Flow Gal.	Test Plant Feed, Gal.	Cu. Ft. Gal.	Per cent to No. 1 Tank.	Tank No. 1.	Tank No. 2.	Screened Sewage, Per cent.	Infl.	Effl.	Per cent Removal.	Infl.	Effl.	Per cent Removal.	Infl.	Infl.	Per cent Removal.	Infl.	Effl.	Per cent Removal.
22.....	858,000	63,700	1.13	65	60	85	.47	447	52	88.3	27	13	51.8	443	335	19.9	1390	803	42.2
23.....	957,000	65,600	1.16	61	66	61	.30	360	22	93.8	25	30	......	444	376	15.3	1113	745	33.1
24.....	953,000	62,600	1.21	62	52	66	.24	284	35	87.9	70	37	47.2	429	339	21.0	1040	830	20.2
25.....	916,000	63,800	1.20	62	41	61	.24	290	18	93.6	72	40	44.4	389	285	26.7	1030	845	17.9
26.....	921,000	66,900	1.17	61	32	50	.25	273	18	93.3	73	23	68.5	377	399	....	1041	808	22.3
27.....	915,000	67,900	1.15	62	47	51	.24	277	18	93.2	60	37	38.3	453	271	40.1	1072	790	26.3
28.....	860,000	65,100	1.20	61	47	51	.13	220	22	89.8	56	43	23.2	427	429	....	915	790	13.7
29.....	839,000	64,000	1.22	62	54	50	.28	332	13	96.2	67	34	49.3	493	488	1.0	1077	800	25.8
30.....	838,000	63,400	1.15	63	71	67	.23	295	20	93.2	55	32	41.8	459	460	....	957	800	16.4
31.....	857,000	65,800	1.16	61	59	64	.20	257	25	90.0	55	35	36.3	459	475	....	820	820	0.0
Sept. 1	819,000	62,600	1.25	60	47	56	.25	287	23	91.8	35	54	......	445	329	26.1	1060	850	19.8
Ave...	885,000	64,600	1.18	62	52	60	.26	302	24	92.1	54	34	37.0	438	382	12.8	1047	808	22.9

TABULATION OF CHEMICAL DATA AND DAILY OPERATING CONDITIONS—AUG. 22-SEPT. 1—Continued.

Date.	Free Ammonia.			Albuminoid Ammonia.			Total Organic Nitrogen.			Nitrates.			Nitrites.				
Aug.	Infl.	Effl.	Per cent Removal.	Infl.	Effl.	Per cent Removal.	Infl.	Effl.	Per cent Removal.	Infl.	Effl.	Per cent Removal.	Infl.	Effl.	Per cent Removal.	Effluent Stability, Days.	Influent Chlorides, P. P. M.
22............	20.8	18.5	11.0	11.3	1.6	86.0	28.0	8.0	71.4	0.9	0.1	88.8	.01	0.0	100.0	1.0	191
23............	16.3	14.7	9.8	7.2	1.7	76.4	18.0	5.2	71.1	0.9	0.1	88.8	.06	0.0	100.0	1.5	101
24............	17.6	17.2	2.3	4.0	1.7	57.5	12.0	6.0	50.0	2.6	0.1	96.1	.02	0.0	100.0	3.0	134
25............	18.3	17.2	6.0	4.1	1.9	53.7	14.0	4.0	71.5	0.7	0.1	85.6	.04	0.0	100.0	3.0	117
26............	18.7	18.0	3.8	4.1	2.3	43.8	14.0	6.0	57.2	0.2	0.2	0.0	.05	0.01	80.0	2.0	140
27............	22.0	20.4	7.2	3.3	2.0	39.4	14.0	5.2	67.6	0.3	0.1	66.6	.03	0.0	100.0	2.0	129
28............	22.8	22.0	3.6	4.2	1.9	54.8	14.0	4.0	71.5	0.6	0.1	83.3	.04	0.0	100.0	2.0	111
29............	16.7	18.7	....	4.4	2.0	54.5	12.0	4.0	66.6	0.5	0.1	80.0	.02	0.0	100.0	2.5	152
30............	20.0	20.0	0.0	3.2	1.9	40.6	14.0	4.0	71.5	0.6	0.1	83.0	.06	0.0	100.0	1.5	123
31............	21.5	20.0	6.9	3.2	1.9	40.6	10.0	14.0	....	0.4	0.0	100.0	.05	0.0	100.0	3.0	195
Sept. 1........	18.1	21.6	....	3.2	1.9	40.6	14.0	4.0	71.5	0.4	0.1	75.0	.02	0.0	100.0	1.0	130
Ave...........	19.3	18.9	2.1	4.7	1.9	59.6	15.0	5.9	60.7	0.7	0.1	87.4	.04	0.0	100.0	2.0	138

TABULATION OF CHEMICAL DATA AND DAILY OPERATING CONDITIONS—SEPT. 2-20.

Date.	Champaign Sewage.		Air Used.		Per cent Sludge by Vol.		Settle-able Solids.	Turbidity.			Oxygen Consumed.			Alkalinity.			Residue on Evap.		
Sept.	Total Flow Gal.	Test Plant Feed.	Cu. Ft. Gal.	Per cent No. 1 Tank.	Tank No. 1.	Tank No. 2	Screened Sewage, Per cent.	Infl.	Effl.	Per cent Removal.	Infl.	Effl.	Per cent Removal.	Infl.	Effl.	Per cent Removal.	Infl.	Effl.	Per cent Removal.
2.....	1,107,000	64,100	1.19	59	43.5	67	.27	347	22	93.8	38	60	......	425	483	....	1150	830	27.8
3.....	1,623,000	59,700	1.39	59	61.5	75	.20	363	17	95.6	37	53	......	343	420	....	995	700	29.7
4.....	1,263,000	65,200	1.45	60	52	55	.19	200	22	89.0	43	27	37.2	324	393	....	905	700	22.7
5.....	1,223,000	67,200	1.39	59	37	40	.19	198	22	89.0	49	32	34.8	404	406	....	950	772	18.8
6.....	1,083,000	68,600	1.40	59	44	32	.25	228	27	88.3	65	28	56.9	431	402	6.7	995	855	14.1
7.....	1,109,000	67,200	1.43	58	53	52	.22	207	18	91.6	53	30	43.5	434	445	....	1045	900	13.8
8.....	940,000	67,500	1.44	58	56	48	.16	222	18	92.0	50	30	40	420	444	....	1008	855	15.2
9.....	923,000	64,450	1.47	58	45	62	.17	223	17	92.8	57	32	43.9	433	453	....	963	856	11.1
10.....	906,000	67,500	1.41	58	55	73	.25	252	22	91.6	53	30	43.5	455	451	0.9	882	750	15.0
11.....	787,000	67,200	1.45	59	59	74	.24	230	28	87.7	61	35	34.0	448	450	....	950	760	20.0
12.....	939,000	67,600	1.43	61	61	79	.18	259	10	96.2	53	30	50.8	455	473	....	1050	800	23.8
13.....	954,000	66,100	1.43	61	58	85	.22	240	13	94.4	62	31	41.6	445	476	....	990	795	19.7
14.....	929,000	67,700	1.41	60	41	85	.23	272	10	96.3	63	30	51.7	476	463	2.7	1022	790	22.7
15.....	892,000	68,100	1.41	64	36	83	.20	270	10	96.3	90	25	72.3	494	469	5.1	980	750	23.5
16.....	1,238,000	63,900	1.50	61	41	80	.26	327	10	97.0	47	27	42.6	435	436	....	1060	757	28.6
17.....	1,114,000	66,400	1.42	61	33	72	.13	237	34	85.9	53	29	50.8	440	405	7.9	897	820	8.6
18.....	950,000	69,600	1.39	61	38.5	59	.20	263	90	65.9	59	37	30.2	476	429	9.9	1010	965	4.5
19.....	1,108,000	66,700	1.44	62	40	70	.30	373	155	58.7	53	49	17.0	486	454	6.6	1020	980	3.9
20.....	1,227,000	68,900	1.39	61	40	66	.23	303	80	73.7	53	28	47.2	397	457	....	960	870	9.4
Ave...	1,069,000	66,500	1.41	60	47	66	.22	264	26	90.1	55	34	38.2	433	443	....	991	816	17.7

TABULATION OF CHEMICAL DATA AND DAILY OPERATING CONDITIONS—SEPT. 2-20—Continued.

Date.	Free Ammonia.			Albuminoid Ammonia.			Total Organic Nitrogen.			Nitrates.			Nitrites.				
Sept.	Infl.	Effl.	Per cent Removal.	Infl.	Effl.	Per cent Removal.	Infl.	Effl.	Per cent Removal.	Infl.	Effl.	Per cent Removal.	Infl.	Effl.	Per cent. Removal.	Effluent Stability, Days.	Influent Chlorides, P. P. M.
2..........	18.5	24.5	....	3.3	1.9	42.5	14	4.0	71.5	0.8	0.1	82.8	.06	.00	100.0	3	122
3..........	11.3	22.3	....	3.3	1.6	51.5	14	4.0	71.5	1.8	0.1	94.6	.40	.00	100.0	2	85
4..........	11.2	22.4	....	1.9	1.6	15.8	18	4.0	77.7	4.0	0.3	92.6	.70	.16	77.4	5	77
5..........	13.4	19.2	....	2.4	1.6	33.3	14	4.0	71.5	2.4	1.0	58.4	.23	.24	....	3	90
6..........	15.7	19.0	....	2.7	1.2	55.6	8	4.0	50.0	1.1	1.7	....	.12	.64	....	4	102
7..........	19.1	16.7	12.3	3.3	1.5	54.6	14	2.8	80.1	0.8	2.3	....	.09	.91	....	8	131
8..........	17.6	17.7	....	3.1	1.3	58.1	10	2.8	72.0	1.0	1.8	....	.07	.93	....	10	131
9..........	16.0	19.0	....	4.5	1.9	57.9	12	2.8	76.9	0.9	1.3	....	.07	.48	....	10	93
10..........	19.0	17.6	7.4	3.2	1.6	50.0	10	2.8	72.0	0.8	1.3	....	.03	.59	....	8	96
11..........	19.6	18.7	4.6	4.1	1.7	58.8	10	2.8	72.0	0.7	0.8	....	.02	.32	....	3	119
12..........	19.5	20.6	....	4.1	1.6	61.1	12	5.2	56.8	0.6	0.1	83.4	.03	.12	....	6	109
13..........	22.4	19.0	15.2	4.1	1.5	63.5	10	2.8	72.0	0.8	0.0	100.0	.03	.00	100.0	2	109
14..........	26.5	17.8	32.8	3.3	1.7	48.6	10	2.8	72.0	0.6	0.4	33.3	.02	.19	....	1.5	111
15..........	27.0	18.7	30.8	6.0	1.6	73.2	14	4.0	71.5	0.8	1.3	....	.01	.46	....	7	126
16..........	25.3	12.3	51.3	3.6	1.7	52.9	12	2.8	76.9	1.5	3.7	....	.21	1.6	....	10	99
17..........	20.6	9.0	56.2	3.1	2.0	35.5	2.8	5.2	....	0.8	6.2	....	.07	3.2	....	10	88
18..........	26.9	19.0	29.4	4.4	2.1	52.2	24	0.4	98.4	0.8	5.8	....	.09	2.65	....	8	91
19..........	21.3	22.6	....	4.7	3.6	23.4	20	20	0.0	0.6	0.7	....	.03	1.04	....	1	108
20..........	21.4	13.5	32.0	4.7	2.3	51.2	10	4.0	60.0	0.9	1.4	....	.05	.82	....	10	103
Ave..........	19.6	18.4	6.1	3.5	1.7	51.4	13	4.3	65.6	1.14	1.6	....	.12	.76	....	6.2	105

TABULATION OF CHEMICAL DATA AND DAILY OPERATING CONDITIONS—SEPT. 21-28.

Date.	Champaign Sewage.		Air Used.		Per cent Sludge by Vol.		Settle-able Solids.	Turbidity.			Oxygen Consumed.			Alkalinity.			Residue on Evap.		
Sept.	Total Flow Gal.	Test Plant Feed.	Cu. Ft. Gal.	Per cent to No. 1 Tank.	Tank No. 1.	Tank No. 2	Overflow.	Infl.	Overflow.	Effl.	Infl.	Overflow.	Effl.	Infl.	Overflow.	Effl.	Infl.	Overflow.	Effl.
21.....	1,117,000	61,230	1.25	60	45	65	4.6	280	70	40	50	45	26	432	460	438	1030	......	810
22.....	1,099,000	64,870	1.08	65	38.5	59	5.0	250	55	10	26	24	27	476	486	460	910	......	760
23.....	1,057,000	65,440	1.06	63	45	76	6.1	300	60	10	33	32	24	496	492	472	930	......	680
24.....	1,272,000	68,730	1.03	65	48.5	86	7.3	360	75	43	60	36	28	426	424	486	1010	......	770
25.....	1,020,000	65,350	1.09	64	49	59	11.5	260	60	40	37	28	22	436	420	410	980	......	740
26.....	1,086,000	65,600	1.09	64	44	71	11.0	280	95	90	52	26	32	478	480	460	1020	......	870
27.....	1,070,000	68,910	1.01	66	44	63	8.7	240	70	100	53	25	33	480	472	474	950	......	950
28.....	1,033,000	72,660	.98	65	41.5	62	11.0	280	140	190	44	55	26	464	480	472	1110	......	980
Ave...	1,094,300	66,600	1.07	64	44.4	68	8.2	281	78	65	44	34	27	461	464	459	991	......	820
Per cent removal........			......	......	......	......	......	....	72.3	76.9	.....	22.7	38.6	....	......	0.4	......	......	17.2

TABULATION OF CHEMICAL DATA AND DAILY OPERATING CONDITIONS—SEPT. 21-28—Continued.

Date.	Free Ammonia.			Albuminoid Ammonia.			Total Organic Nitrogen.			Nitrates.			Nitrites.				
Sept.	Infl.	Overflow.	Effl.	Infl.	Overflow.	Effl.	Infl.	Overflow.	Effl.	Infl.	Overflow.	Effl.	Infl.	Overflow.	Effl.	Effluent Effluent Days.	Influent Chlorides, P. P. M.
21............	19	17	13.0	2.8	5.2	2.0	10	24	8.0	2.0	0.3	2.0	.1	.00	1.00	1.0	154
22............	19.7	17.6	10.0	3.2	0.0	0.0	12	10	2.8	0.1	0.1	1.0	.0	.00	.25	1.5	96
23............	22	20	12.0	3.2	0.0	0.0	16	18	8.0	0.3	0.1	0.7	.0	.00	.28	4.0	100
24............	18	16.6	19.0	12.8	0.0	0.0	18	10	5.2	0.7	0.1	0.1	.1	.00	.00	3.5	104
25............	20	17.6	14.0	6.4	0.0	0.0	10	18	4.0	1.0	0.3	0.3	.1	.00	.15	4.5	118
26............	20	19	18.0	8.0	0.0	0.0	12	18	10.0	0.7	0.3	0.3	.0	.00	.15	1.5	108
27............	22	16.6	16.5	4.0	2.8	2.0	20	24	16.0	0.7	0.1	0.1	.02	.00	.00	1.5	106
28............	24	23	20.6	4.0	6.8	5.6	16	14	24.0	0.3	0.7	0.7	.0	.00	.00	4.0	162
Ave..........	20.6	18.4	15.4	5.6	1.8	1.2	14.3	17	9.8	0.7	0.3	0.7	.04	.00	.23	3.0	119
Per cent remov'l	......	10.7	39.5	......	67.8	78.6	.....	......	31.5	......	52.1	0.0	......	100	....	....	......

TABULATION OF CHEMICAL DATA AND DAILY OPERATING CONDITIONS—SEPT. 29-OCT. 6.

Date.	Champaign Sewage.		Air Used.		Per cent Sludge by Vol.		Settleable Solids.	Turbidity.			Oxygen Consumed.			Alkalinity.			Residue on Evap.		
Sept.	Total Flow Gal.	Test Plant Feed.	Cu. Ft. Gal.	Per cent to No. 1 Tank.	Tank No. 1.	Tank No. 2.	Overflow.	Infl.	Overflow.	Effl.	Infl.	Overflow.	Effl.	Infl.	Overflow.	Effl.	Infl.	Overflow.	Effl.
29.....	1,319,000	60,250	1.15	65	51	68	15.0	300	60	160	45	32	30	440	426	470	960	......	860
30.....	1,238,000	64,260	1.10	65	51	69	13.0	280	75	10	32	35	15	452	440	432	910	......	700
Oct. 1	1,125,000	61,460	1.20	65	57	79	25.0	240	85	150	50	28	40	476	476	470	910	......	820
2.....	941,000	56,200	1.16	65	82	95	20.0	230	90	180	52	35	27	478	500	474	930	......	880
3.....	1,087,000	68,300	1.08	65	69	94	25.0	340	130	380	60	34	34	490	500	494	1080	......	950
4.....	1,059,000	67,800	1.09	65	54	52	10.0	290	110	300	60	66	34	486	500	496	1050	......	990
5.....	1,038,000	64,800	1.08	66	68	93	30.0	280	70	320	52	33	27	480	484	484	960	......	940
6.....	1,074,000	67,400	1.05	66	54	77	20.0	270	75	220	52	30	34	488	478	490	910	......	910
Ave..	1,234,600	63,810	1.11	65	61	78	19.8	279	87	215	50	37	30	474	457	476	963	......	881
Per cent removal	....	......	......	......	......	......	......	....	68.8	22.9	.....	25.9	39.9	....	4.8	....	......	......	8.5

TABULATION OF CHEMICAL DATA AND DAILY OPERATING CONDITIONS—SEPT. 29-OCT. 6—Continued.

Date.	Free Ammonia.			Albuminoid Ammonia.			Total Organic Nitrogen.			Nitrates.			Nitrites.				
Sept.	Infl.	Overflow.	Effl.	Infl.	Overflow.	Effl.	Infl.	Overflow.	Effl.	Infl.	Overflow.	Effl.	Infl.	Overflow.	Effl.	Effluent Stability, Days.	Influent Chlorides, P. P. M.
29.............	18.6	17.6	18.1	4.0	1.2	2.8	18	24	16	0.3	0.7	0.3	.15	.0	.0	2.5	90
30.............	21.4	20.0	17.6	4.0	2.0	2.8	10	4	4	1.3	1.3	0.7	.0	.0	.15	4.0	88
Oct. 1........	24.0	22.0	21.6	2.8	2.0	2.0	10	28	10	0.3	0.5	0.1	.0	.0	.0	3.5	96
2.............	23.6	23.0	22.0	2.8	2.0	2.0	10	28	20	0.7	0.5	0.5	0.5	.0	.0	2.0	114
3.............	22.7	21.6	23.6	4.0	2.0	2.8	14	28	20	0.3	1.0	0.3	.0	.0	.0	1.5	116
4.............	24.0	21.6	22.0	4.0	2.8	2.0	8	7	20	0.7	0.3	0.3	.10	.0	.0	3.0	110
5.............	23.0	23.0	20.4	4.8	2.0	2.0	14	28	17	0.5	0.1	0.1	.10	.0	.0	3.5	96
6.............	25.0	23.0	20.6	2.8	2.0	2.8	14	28	18	0.7	6.0	2.5	.0	.0	.0	1.0	110
Ave..........	22.8	21.5	20.7	3.7	2.0	2.4	12.3	22	15.6	0.6	1.3	0.6	.05	.0	.02	2.6	103
Per cent remov'l	......	5.7	9.2	......	45.9	35.2	.....	......	....	......	......	00	......	100	60.0	......	......

TABULATION OF CHEMICAL DATA AND DAILY OPERATING CONDITIONS—OCT. 7-16.

Date.	Champaign Sewage.		Air Used.		Per cent Sludge by Vol.		Settle-able Solids.	Turbidity.			Oxygen Consumed.			Alkalinity.			Residue on Evap.		
Oct.	Total Flow Gal.	Test Plant Feed.	Cu. Ft. Gal.	Per cent to No. 1 Tank.	Tank No. 1.	Tank No. 2.	Overflow.	Infl.	Overflow.	Effl.	Infl.	Overflow.	Effl.	Infl.	Overflow.	Effl.	Infl.	Overflow.	Effl.
7.....	1,484,000	84,000	.57	67	71	95	16.0	200	95	10	52	107	23	386	406	430	830	......	820
8.....	1,323,000	102,400	.64	67	50	95	10.2	240	60	10	38	32	12	450	448	438	940	......	680
9.....	1,036,000	102,800	.62	66	40	96	5.0	240	65	10	45	38	17	464	454	458	980	......	710
10.....	1,137,000	117,100	.65	67	40	93	5.0	290	90	10	63	33	21	482	498	478	1110	......	730
11.....	1,132,000	103,200	.63	66	42	92	3.0	280	105	10	65	38	31	484	476	476	950	......	790
12.....	1,086,000	105,800	.64	66	44	93	3.0	330	125	10	56	40	30	488	492	482	970	......	755
13.....	1,093,000	104,400	.63	67	45	91	2.3	260	100	15	67	35	23	438	500	476	950	......	690
14.....	1,156,000	101,800	.64	66	42	94	2.5	280	120	15	55	32	25	476	486	480	1060	......	780
15.....	1,090,000	101,700	.65	66	42	94	3.0	270	100	25	52	29	......	470	474	480	920	......	860
16.....	938,000	100,300	.59	66	45	96	4.0	240	90	30	58	20	23	468	472	470	900	......	740
Ave....	1,147,500	102,350	.63	66	46	94	5.4	263	95	15	55	40	23	461	471	467	961	......	755
Per cent removal........		......	......	......	......	......	......	....	63.9	94.3	.....	27.2	58.2	....	......	....	......	......	21.4

TABULATION OF CHEMICAL DATA AND DAILY OPERATING CONDITIONS—OCT. 7-16—Continued.

Date.	Free Ammonia.			Albuminoid Ammonia.			Total Organic Nitrogen.			Nitrates.			Nitrites.			Effluent Stability, Days.	Influent Chlorides, P. P. M.
Oct.	Infl.	Overflow.	Effl.	Infl.	Overflow.	Effl.	Infl.	Overflow.	Effl.	Infl.	Overflow.	Effl.	Infl.	Overflow.	Effl.		
7............	17.4	22.0	16.0	2.0	2.0	1.2	5.2	28	8.0	2.0	0.3	0.5	.30	.00	.10	3	78
8............	21.0	18.0	16.0	4.0	1.6	1.2	14.0	16	5.0	0.3	0.1	0.7	.00	.00	.30	8	88
9............	22.0	20.0	20.0	4.8	2.8	1.2	12.0	14	4.0	1.0	0.1	0.5	.00	.00	.18	7	104
10............	32.0	19.0	22.0	5.2	4.0	1.6	12.0	14	14.0	1.0	0.5	0.7	.04	.00	.01	2	128
11............	20.6	18.0	20.0	2.0	2.8	1.3	18.0	20	5.2	1.3	0.3	0.7	.05	.00	.00	6	94
12............	22.0	19.0	19.0	5.2	2.0	2.0	10.0	24	10.0	1.0	0.3	0.1	.02	.00	.00	5	110
13............	21.0	20.0	18.6	4.8	4.4	2.0	14.2	12	5.2	1.0	0.1	0.1	.12	.00	.00	2	94
14............	21.0	21.0	19.0	4.0	2.4	2.0	10.0	12	4.0	1.3	0.3	0.1	.10	.00	.00	2	94
15............	24.0	23.0	22.0	8.0	2.0	2.0	14.0	18	6.0	0.3	0.1	0.1	.08	.00	.00	1	100
16............	33.0	24.0	22.0	2.6	1.2	1.6	16.0	18	5.2	0.5	0.1	0.1	.15	.00	.00	1.5	118
Ave..........	23.4	20.4	19.5	4.3	2.5	1.6	12.5	17.6	6.7	1.0	0.2	0.4	.09	.00	.06	3.7	101
Per cent remov'l	......	12.8	16.7	......	41.8	62.8	.....	......	46.4	......	80.0	60.0	......	100	33.3	......	......

Remarks: During run from Oct. 7 to 16, inclusive, an average of 45.5 per cent of the overflow was by passed.
During run from Oct. 17 to 31, inclusive, an average of 44.9 per cent of the overflow was by passed.

TABULATION OF CHEMICAL DATA AND DAILY OPERATING CONDITIONS—OCT. 17-31.

Date.	Champaign Sewage.		Air Used.		Per cent Sludge by Vol.		Settleable Solids.	Turbidity.			Oxygen Consumed.			Alkalinity.			Residue on Evap.		
Oct.	Total Flow Gal.	Test Plant Feed.	Cu. Ft. Gal.	Per cent to No. 1 Tank.	Tank No. 1.	Tank No. 2.	Overflow.	Infl.	Overflow.	Effl.	Infl.	Overflow.	Effl.	Infl.	Overflow.	Effl.	Infl.	Overflow.	Effl.
17.....	1,218,000	86,100	.71	60	52	95	3.0	300	100	20	58	37	23	464	464	474	1040	......	790
18.....	1,452,000	102,100	.67	59	52	96	5.0	300	160	25	65	50	30	470	478	458	1050	......	740
19.....	1,498,000	99,200	.69	64	41	96	6.5	280	170	30	48	35	28	484	470	480	880	......	730
20.....	1,614,000	99,100	.69	60	39	85	5.0	270	100	32	75	35	30	496	508	480	990	......	750
21....	1,093,000	98,400	.71	60	28	66	......	290	100	35	50	34	22	476	476	472	990	......	780
22.....	1,171,000	102,100	.76	61	36	66	6.8	270	130	20	60	28	22	474	482	480	920	......	730
23.....	959,000	102,600	.78	61	36	85	3.2	280	140	25	60	30	24	480	484	480	1100	......	730
24.....	1,089,000	87,600	.59	66	38	74	3.0	290	115	15	67	32	25	482	484	480	1060	......	730
25.....	1,042,000	83,600	.65	66	50	72	10.0	290	170	20	76	50	20	488	514	496	1040	......	730
26.....	1,215,000	84,300	.58	66	51	70	6.5	340	130	25	67	32	25	482	442	480	1030	......	750
27.....	1,095,000	88,600	.58	66	38	54	1.5	300	110	15	41	28	12	466	476	456	1110	......	790
28.....	1,216,000	95,200	.59	66	50	59	4.5	290	140	20	38	20	15	460	458	476	1250	......	760
29.....	1,340,000	94,100	.55	66	41	54	5.0	330	100	25	50	26	23	444	440	438	940	......	710
30.....	1,115,000	93,600	.56	66	34	36	6.0	250	130	30	58	30	26	468	468	464	930	......	720
31.....	1,065,000	89,900	.66	66	38	48	6.0	370	150	85	98	40	26	490	490	472	1080	......	820
Ave...	1,212,700	93,760	.65	64	42	70	5.1	297	129	28	61	34	23	475	409	472	1027	......	750
Per cent removal........			......	......	......	......	......	....	56.6	90.6	.....	44.2	62.2	....	13.9	0.7	......	......	26.9

TABULATION OF CHEMICAL DATA AND DAILY OPERATNG CONDITONS—OCT. 17-31—Continued.

Date.	Free Ammonia.			Albuminoid Ammonia.			Total Organic Nitrogen.			Nitrates.			Nitrites.			Effluent Stability, Days.	Influent Chlorides, P. P. M.
Oct.	Infl.	Overflow.	Effl.	Infl.	Overflow.	Effl.	Infl.	Overflow.	Effl.	Infl.	Overflow.	Effl.	Infl.	Overflow.	Effl.		
17	24.0	21.0	22.0	4.0	2.8	2.0	16	14	4.0	0.5	0.3	0.1	.12	.00	.00	1.5	100
18	26.0	23.0	21.0	5.2	1.2	1.2	18	18	4.0	0.5	0.5	0.3	.08	.00	.00	3	108
19	29.0	22.0	20.0	4.0	5.2	2.0	10	22	2.8	0.5	0.5	0.1	.00	.00	.00	1	96
20	25.0	21.4	19.6	4.0	4.0	2.0	12	26	2.8	1.3	0.5	0.1	.05	.00	.00	1.5	112
21	29.0	21.0	20.0	4.0	1.6	2.0	14	12	4.0	0.3	0.1	0.1	.00	.00	.00	2.5	116
22	25.0	23.0	22.0	4.0	2.0	2.0	14	18	5.2	1.3	0.1	0.1	.05	.00	.00	7	112
23	29.0	25.0	23.0	5.2	2.0	2.0	4	4.5	1.5	0.7	0.3	0.1	.04	.00	.00	3	160
25	24.0	20.0	23.0	5.2	2.4	1.2	12	16	2.8	1.0	0.7	0.3	.03	.00	.00	3	100
24	25.0	23.4	22.0	4.0	3.6	1.2	16	26	4.0	1.0	0.1	0.1	.05	.00	.00	3	110
26	28.0	21.0	22.0	4.8	2.8	0.8	16	18	5.2	1.5	0.3	0.3	.15	.00	.02	2	112
27	23.0	21.0	20.0	5.2	2.8	0.8	16	14	2.8	0.7	0.1	0.1	.15	.00	.00	3	138
28	29.0	20.0	19.0	4.0	4.0	1.2	12	24	6.0	0.7	0.3	0.1	.00	.00	.00	5	296
29	24.6	23.0	21.0	4.0	2.8	0.4	16	20	4.0	1.3	0.1	0.1	.00	.00	.00	3	96
30	29.0	24.0	24.0	5.2	2.8	2.4	16	24	6.0	1.0	0.3	0.1	.18	.00	.00	6	94
31	27.0	24.0	24.0	5.2	3.2	1.2	16	26	10.0	1.3	0.5	0.1	.03	.00	.00	2.5	118
Ave.	26.4	22.2	21.5	4.5	2.9	1.5	14.2	19.7	4.3	0.9	0.3	0.1	.06	.00	.00	3.1	124
Per cent remov'l	......	15.9	18.6	......	35.5	66.6	.....	......	69.3	......	66.6	88.9	......	100	100	......	......

TABULATION OF CHEMICAL DATA AND DAILY OPERATING CONDITIONS—NOV. 16-30.

Date.	Champaign Sewage.		Air Used.		Per cent Sludge by Vol.		Settle-able Solids.	Turbidity.			Oxygen Consumed.			Alkal'nity.			Residue on Evap.		
Nov.	Total Flow Gal.	Test Plant Feed.	Cu. Ft. Gal.	Per cent to No. 1 Tank	Tank No. 1.	Tank No. 2	Overflow.	Infl.	Overflow.	Effl.	Infl.	Overflow.	Effl.	Infl.	Overflow.	Effl.	Infl.	Overflow.	Effl.
16.....	1,556,000	26,800	2.78	67	......	......	.20	500	150	120	38	56	46	360	420	470	1160	......	950
17.....	2,252,000	43,700	2.46	57	......	......	.10	280	80	75	55	40	35	406	398	424	1050	......	830
18.....	2,302,000	72,200	1.95	59	4	1	.08	270	55	50	35	25	28	270	288	366	1080	......	810
19.....	2,229,000	77,800	1.34	59	6	1	.03	90	50	33	40	17	20	252	254	238	1080	......	958
20.....	2,008,000	79,000	1.27	61	6	2	.03	75	45	30	26	25	27	302	292	260	1020	......	1010
21.....	1,976,000	79,900	1.24	62	7	2	.02	140	37	25	28	16	16	364	340	332	1010	......	980
22.....	1,932,000	90,800	1.08	61	9	3	.00	140	30	20	20	17	23	366	344	354	1010	......	950
23.....	1,929,000	94,100	1.04	62	10	3	.00	160	30	25	30	25	22	376	358	364	970	......	860
24.....	2,181,000	94,100	1.04	62	12	3	.00	130	85	60	33	23	20	368	366	358	910	......	820
25.....	2,239,000	91,900	1.05	62	14	2	.00	190	60	45	33	21	20	386	374	380	840	......	800
26.....	2,195,000	91,200	1.05	62	16	2	.00	75	25	20	18	20	16	376	336	370	870	......	810
27.....	2,244,000	90,000	1.06	63	22	2	.00	105	65	37	25	24	30	372	372	362	830	......	770
28.....	2,194,000	92,900	1.03	63	26	2	.05	190	75	80	35	35	30	390	386	390	890	......	830
29.....	2,243,000	91,800	1.04	63	43	2	.00	170	55	75	30	23	18	392	390	390	890	......	810
30.....	2,350,000	91,700	1.04	63	55	1	.00	150	55	55	26	23	20	394	394	402	940	......	800
Ave...	2,122,000	80,530	1.33	62	18	2	.03	178	59	50	32	26	25	358	354	364	977	......	865
Per cent removal........		......	......	......	......	......	......	....	66.6	72.0	.....	18.7	21.8	....	1.1	....	......	......	11.5

TABULATION OF CHEMICAL DATA AND DAILY OPERATING CONDITIONS—NOV. 16-30—Continued.

Date.	Free Ammonia.			Albuminoid Ammonia.			Total Organic Nitrogen.			Nitrates.			Nitrites.			Effluent Stability, Days.	Influent Chlorides, P. P. M.
Nov.	Infl.	Overflow.	Effl.	Infl	Overflow.	Effl.	Infl.	Overflow.	Effl.	Infl.	Overflow.	Effl.	Infl.	Overflow.	Effl.		
16	15.0	17.6	21.0	0.0	2.8	2.8	12	10.0	10.0	1.0	1.3	0.5	.50	.60	.25	......	80
17	17.8	17.0	25.0	2.4	2.4	2.8	10	8.0	8.0	5.0	3.5	4.0	.50	.60	.50	......	112
18	12.6	11.0	14.0	1.2	2.0	1.6	10	6.0	6.0	22.0	12.0	6.0	.70	.60	.60	1	86
19	7.0	4.0	6.6	0.4	0.4	1.2	8	6.0	5.2	5.5	5.0	6.0	1.20	1.12	1.12	2	70
20	5.4	6.0	6.6	1.2	0.0	0.4	8	6.0	4.0	24.0	24.0	26.0	1.60	1.20	1.20	2	66
21	10.6	6.0	8.0	2.0	0.4	1.2	10	6.0	5.2	20.0	20.0	18.0	3.00	2.00	2.00	8	156
22	8.0	7.6	8.0	2.4	0.0	0.0	10	5.2	4.0	6.0	7.0	7.0	2.20	2.20	2.00	2	110
23	11.0	8.6	12.0	2.0	0.4	0.4	8	6.0	4.0	3.0	3.0	6.5	.05	1.00	1.00	3	78
24	8.0	9.6	9.0	0.0	0.0	0.0	10	8.0	6.0	4.5	5.0	6.5	1.12	1.00	1.20	5	86
25	11.6	8.6	12.0	4.0	0.4	1.2	14	6.0	4.0	1.0	5.0	6.0	.00	.50	.65	2	74
26	9.6	14.0	11.0	1.2	1.2	0.4	8	6.0	4.0	0.5	5.5	4.5	.00	1.25	.70	2	116
27	12.0	13.6	14.3	2.8	2.0	1.2	10	6.0	4.0	1.3	6.0	3.5	.15	1.00	1.00	2	64
28	9.6	12.0	12.6	2.4	1.2	1.2	12	5.2	8.0	1.5	4.5	4.5	.45	.45	.45	1.5	68
29	12.6	14.0	11.6	2.4	2.0	0.4	12	5.2	5.2	1.3	4.0	3.5	.45	.45	.45	2	86
30	11.0	13.4	13.4	1.2	0.4	1.2	16	5.2	5.2	0.5	3.0	2.5	.00	.45	.45	2	98
Ave.	10.8	10.9	12.3	1.7	1.0	1.0	10.5	6.3	5.5	6.5	7.2	7.0	.79	.96	.90	2.6	90
Per cent remov'l	......	......	....	......	41.2	41.2	.....	40.0	47.6	......	......	....	......	......	....	......	......

TABULATION OF CHEMICAL DATA AND DAILY OPERATING CONDITIONS—DEC. 1-7.

Date.	Champaign Sewage.		Air Used.		Per cent Sludge by Vol.		Settle-able Solids.	Turbidity.			Oxygen Consumed.			Alkalinity.			Residue on Evap.		
Dec.	Total Flow Gal.	Test Plant Feed.	Cu. Ft. Gal.	Per cent to No. 1 Tank.	Tank No. 1.	Tank No. 2.	Overflow.	Infl.	Overflow.	Effl.	Infl.	Overflow.	Effl.	Infl.	Overflow.	Effl.	Infl.	Overflow.	Effl.
1.....	2,087,000	66,100	.96	63	65	0	0.0	280	40	50	48	20	21	....	......	....	940	......	740
2.....	1,911,000	65,900	.95	65	75	0	0.0	170	35	35	20	13	20	370	368	360	910	......	740
3.....	1,711,000	66,900	.96	64	80	0	0.5	150	15	20	32	18	15	366	386	378	840	......	730
4.....	1,785,000	65,300	.98	64	84	0	0.5	140	20	15	31	16	21	374	384	386	820	......	690
5.....	1,842,000	78,500	.79	65	83	1	2.0	200	190	27	32	14	14	400	398	398	900	......	730
6.....	1,701,000	91,400	.72	64	75	17	4.5	210	250	25	54	23	12	404	406	398	1080	......	750
7.....	1,980,000	92,300	.71	66	73	47	......	....	......	......	.....	......	......	....	......	....	......	......	....
Ave..	1,859,500	75,200	.87	64	76	9	1.2	190	92	29	36	17	17	383	388	384	915	......	730
Per cent removal.......		......	......	......	......	......	......	....	51.6	84.8	.....	52.9	52.9	....	......	....	......	......	20.2

TABULATION OF CHEMICAL DATA AND DAILY OPERATING CONDITIONS—DEC. 1-7—Continued.

Date.	Free Ammonia.			Albuminoid Ammonia.			Total Organic Nitrogen.			Nitrates.			Nitrites.			Effluent Stability, Days.	Influent Chlorides, P. P. M.
Dec.	Infl.	Overflow.	Effl.	Infl.	Overflow.	Effl.	Infl.	Overflow.	Effl.	Infl.	Overflow.	Effl.	Infl.	Overflow.	Effl.		
1.............	16.0	13.0	11.0	2.4	0.0	0.4	14.0	5.2	4.0	1.5	3.5	2.0	.75	.40	.25	5	......
2.............	14.0	14.0	12.0	2.8	1.2	1.2	10.0	5.2	4.0	1.0	1.3	1.0	.45	.00	.10	3	86
3.............	13.6	17.0	14.6	2.0	0.8	1.2	14.0	4.0	6.0	4.5	1.5	2.0	.56	.12	.18	5	70
4.............	17.0	17.0	16.0	2.8	1.2	0.8	14.0	8.0	6.0	5.5	1.5	1.5	.60	.20	.25	10	70
5.............	14.6	17.0	18.0	4.0	4.0	1.2	18.0	18.0	6.0	4.5	1.5	2.0	.40	.18	.20	10	82
6.............	17.0	14.0	17.4	4.0	2.0	1.6	18.0	27.0	6.0	4.0	2.0	1.5	.40	.15	.18	8	80
7.............	......	......	....	......	......	......	....	......	......	......	......	......	......	......	......	7	......
Ave...........	15.4	15.3	14.8	3.0	1.5	1.1	14.6	11.3	5.3	3.5	1.9	1.7	.53	.17	.19	7	77
Per cent remov'l	......	0.6	3.9	......	50.0	63.3	.....	23.3	63.8	......	45.7	51.4	......	67.6	64.1	......	......

TABULATION OF CHEMICAL DATA AND DAILY OPERATING CONDITIONS—DEC. 8-28.

Date.	Champaign Sewage.		Air Used.		Per cent Sludge by Vol.		Settle-able Solids.	Turbidity.			Oxygen Consumed.			Alkalinity.			Residue on Evap.		
Dec.	Total Flow Gal.	Test Plant Feed.	Cu. Ft. Gal.	Per cent to No. 1 Tank.	Tank No. 1.	Tank No. 2.	Overflow.	Infl.	Overflow.	Effl.	Infl.	Overflow.	Effl.	Infl.	Overflow.	Effl.	Infl.	Overflow.	Effl.
8.....	1,818,000	71,700	.78	68	70	58	0.5	180	110	20	50	30	13	392	402	388	870	......	710
9.....	1,908,000	85,800	.76	67	74	63	4.5	185	270	20	55	20	20	416	404	400	890	......	720
10.....	1,741,000	84,900	.76	67	61	68	0.7	190	240	10	30	25	15	402	390	396	930	......	730
11.....	1,568,000	83,400	.77	67	68	66	3.5	190	170	10	20	14	12	382	388	392	930	......	730
12.....	1,590,000	86,100	.74	68	68	65	3.0	230	240	10	64	31	17	428	398	404	950	......	730
13.....	1,607,000	82,300	.75	66	66	70	3.0	220	270	15	25	28	20	412	402	402	900	......	730
14.....	1,420,000	82,800	.77	70	70	73	2.8	190	280	10	50	33	13	414	398	398	780	......	670
15.....	....	87,900	.74	67	71	70	4.0	210	320	10	45	23	20	410	402	406	900	......	700
16.....	1,384,000	80,100	.79	70	68	72	5.5	300	350	5	66	30	10	360	390	390	940	......	680
17.....	....	83,300	.78	70	66	69	1.4	240	160	20	35	10	15	370	342	354	860	......	700
18.....	....	84,300	.77	68	71	65	2.8	180	230	25	48	28	16	384	374	380	920	......	650
19.....	....	83,400	.77	67	64	66	3.5	210	260	10	23	12	10	420	398	392	920	......	730
20.....	....	72,900	.88	68	57	73	3.7	200	190	10	35	15	10	416	398	374	920	......	800
21.....	....	65,200	.97	69	67	77	8.0	260	350	85	68	17	14	420	406	392	1100	......	850
22.....	....	79,500	.80	69	64	78	3.0	210	250	20	47	28	13	400	392	396	960	......	770
23.....	....	81,500	.78	70	71	72	1.8	290	230	28	31	20	10	304	340	346	910	......	750
24.....	....	80,600	.81	70	66	57	0.1	160	85	10	35	18	10	214	318	296	920	800	750
25.....	....	80,900	.80	70	67	64	0.5	100	90	15	27	15	15	330	324	334	870	840	790
26.....	....	83,000	.78	70	64	73	0.2	140	95	15	33	18	10	354	336	336	910	820	820
27.....	....	84,200	.77	70	69	75	0.7	200	115	20	23	13	14	360	350	352	880	830	790
28.....	....	10,900	.81	71	75	65	......	....	......	......	.....	......	......	....	......	......	......	......	......
Ave...		77,800	.79	69	67	68	2.6	204	215	17	40	21	14	379	378	376	913	822	740
Per cent removal........			......	......	......	......	......	....	......	21.5	.....	42.4	65.0	....	0.3	0.8	......	......	18.9

TABULATION OF CHEMICAL DATA AND DAILY OPERATING CONDITIONS—OEC. 8-28—Continued.

Date.	Free Ammonia.			Albuminoid Ammonia.			Total Organic Nitrogen.			Nitrites.			Nitrates.			Effluent Stability, Days.	Influent Chlorides, P. P. M.
Dec.	Infl.	Overflow.	Effl.	Infl.	Overflow.	Effl.	Infl.	Overflow.	Effl.	Infl.	Overflow.	Effl.	Infl.	Overflow.	Effl.		
8	16.0	13.0	14.0	4.0	2.8	1.2	12.0	16.0	4.0	4.0	1.0	1.0	.50	.00	.00	8	64
9	19.0	18.0	17.0	4.0	2.8	1.6	18.0	16.0	4.0	4.5	0.5	0.7	.40	.05	.05	8	74
10	18.6	15.0	17.5	4.0	3.2	0.4	12.0	14.0	4.0	4.0	0.7	1.0	.40	.05	.05	10	112
11	17.0	16.0	15.0	2.8	2.4	1.2	12.0	12.0	4.0	4.0	1.0	1.0	.45	.15	.10	10	60
12	20.0	14.0	17.0	4.8	4.0	1.2	16.0	20.0	2.8	3.0	0.5	1.0	.45	.15	.10	10	90
13	19.0	12.0	13.0	4.0	2.0	1.2	10.0	20.0	2.8	4.0	0.5	0.7	.40	.00	.00	10	74
14	17.0	14.0	13.1	4.0	3.2	4.0	10.0	20.0	4.0	2.5	0.3	0.5	.25	.00	.00	10	118
15	16.0	15.0	15.0	4.0	4.0	2.0	12.0	18.0	12.0	2.5	0.3	0.5	.30	.05	.05	10	88
16	18.0	15.0	16.0	4.0	4.0	1.2	12.0	18.0	4.0	2.5	0.3	0.3	.40	.08	.05	9	72
17	16.0	13.4	13.0	2.0	2.0	1.6	9.4	12.0	3.2	3.5	0.5	1.0	.75	.15	.10	9	72
18	17.0	15.6	15.0	2.8	2.8	0.8	14.0	15.6	3.2	4.5	2.3	2.0	.40	.40	.20	10	66
19	17.0	13.0	15.2	2.8	2.8	2.0	9.6	16.0	3.2	2.1	1.4	0.7	.90	.20	.20	10	92
20	16.4	12.2	13.2	4.0	4.0	2.0	.....	16.0	2.8	3.7	0.5	0.8	.40	.15	.15	9	86
21	17.8	14.8	14.6	5.2	2.0	1.6	14.0	22.0	8.4	2.5	0.3	0.4	.25	.00	.10	9	136
22	14.4	10.8	13.4	4.0	2.8	1.6	12.0	12.0	3.2	4.0	2.0	0.9	.30	.00	.18	10	101
23	10.6	10.0	10.0	3.2	4.0	1.2	12.0	12.0	3.6	4.0	1.4	2.5	.30	.20	.20	10	61
24	9.4	13.2	7.8	2.0	1.2	1.2	9.4	5.0	2.8	8.6	6.6	5.3	.30	.60	.30	10	72
25	18.6	9.4	9.4	2.0	1.6	1.2	8.0	8.4	2.8	11.0	8.0	7.6	.30	.30	.30	10	58
26	17.0	10.6	19.6	3.6	2.0	3.6	9.2	6.0	5.2	9.0	7.2	7.0	.56	.60	.28	10	61
27	12.8	8.8	10.6	2.8	2.8	0.0	11.2	8.0	3.2	7.0	4.4	4.6	.60	.50	.28	10	76
28	......	......	....	......	......	......	14.0	13.2	4.0	......	......	......	......	......	......	10	......
Ave.	16.4	12.9	13.9	3.5	2.8	1.5	11.8	15.1	4.2	4.5	1.9	2.0	.43	.18	.13	9.7	82
Per cent remov'l	......	21.3	15.2	......	20.0	57.1	.....	......	64.4	......	57.8	55.6	......	58.1	69.8	......	......

DATA ON IRON DOSING.

Date	December	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	.28
Iron P.P.M. of Fe	Infl.	0.8	1.4	1.5	1.4	0.8	0.8	0.8	1.2	4.0	1.4	1.2	1.2	0.9	1.8	0.9	2.6	0.8	0.6	0.5	0.8	....
	Overflow	....	....	....	....	....	....	....	....	14.0	6.0	8.0	10.0	9.0	14.0	7.0	12.0	2.0	5.0	5.0	6.0	....
	Effl.	0.8	0.4	0.6	0.4	0.4	0.4	0.8	0.4	0.5	0.3	0.4	0.5	0.8	4.0	0.9	1.4	0.8	0.9	2.4	3.2	....
Fe SO_4	Added lbs.	14.0	25.5	32.2	30.5	38.0	30.7	37.0	35.0	33.0	29.5	31.0	36.5	32.2	26.7	31.7	36.2	36.5	33.0	33.0	32.7	3.95

Total weight of Fe SO_4 added during run.................. 639.2 lbs.
Iron content of Fe SO_4 used.............................. 20.5% Fe
Total weight of Fe added during run....................... 131.3 lbs. or 9.6 p.p.m.